

10/587369

UB-P925

IAP11 Rec'd PCT/PTO 26 JUL 2006

DESCRIPTION

METHOD FOR PRODUCING ALDEHYDE COMPOUND OR KETONE
COMPOUND BY USING MICROREACTOR

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TECHNICAL FIELD

The present invention relates to a method for producing an aldehyde compound or a ketone compound using a microreactor. More particularly, the present invention relates to a method for producing an aldehyde or ketone compound from a primary or secondary alcohol and through the Swern oxidation reaction using a microreactor.

BACKGROUND ART

When the Swern oxidation reaction is used to produce an aldehyde compound or a ketone compound from a primary or secondary alcohol, no waste containing a heavy metal is produced and the reaction can be widely applied to various compounds. Also no excess oxidation arises and epimerization, at the α -position with respect to a carbonyl group, does not arise. Therefore, this method is widely used as an organic synthesis reaction method.

However, the Swern oxidation reaction has a problem in that an activation reaction product of a sulfoxide compound and an intermediate of an alkoxysulfonium salt are thermally unstable and, also, by-products are likely to be produced by Pummerer rearrangement at a temperature of -30°C or higher. To solve this problem, in a conventional method, the reaction temperature must be securely controlled to a low temperature such as -50°C or lower. Such a low temperature reaction is expensive and requires a long reaction time and it is actually difficult to control the temperature. It is difficult to scale up this method from an industrial point of view.

As a trial using a microreactor for an organic chemical reaction, for example, Japanese Unexamined

Patent Publication (Kokai) No. 2002-155007 (Patent Document 1) discloses that a fine-structured reaction system is used so as to produce aldols from aldehydes and/or ketones at a temperature of -10 to +250°C through a catalytic reaction, while Japanese Unexamined Patent Publication (Kokai) No. 2003-113185 (Patent Document 2) discloses a method, for producing an allylboron compound and an alkylboron compound, which comprises reacting a lithium aromatic and an aliphatic compound with a boron compound at a temperature of -60°C to +30°C using a microreactor.

Furthermore, Kohyo (National Publication of Translated Version) No. 2003-506339 (Patent Document 3) discloses a method for a Friedel-Crafts acylation reaction of an acylating agent and strong acid with an organic compound (preferably, an aromatic or heteroaromatic compound) in a microreactor at a temperature of 10 to 90°C. Furthermore, Japanese Unexamined Patent Publication (Kokai) No. 2003-128677 (Patent Document 4) discloses a method, for producing an allylboron and an alkylboron, which comprises reacting a halide of allylmagnesium and alkylmagnesium with a boron compound in a microreactor at a temperature of -60°C to +80°C.

However, there has never been known a method capable of industrially carrying out the Swern reaction of a primary or secondary alcohol using a microreactor.

[Patent Document 1] Japanese Unexamined Patent Publication (Kokai) No. 2002-155007

[Patent Document 2] Japanese Unexamined Patent Publication (Kokai) No. 2003-113185

[Patent Document 3] Japanese Unexamined Patent Publication (Kohyo) (National Publication of Translated Version) No. 2003-506339

[Patent Document 4] Japanese Unexamined Patent Publication (Kokai) No. 2003-128677

DISCLOSURE OF THE INVENTION

An object of the present invention is to provide a method for producing an aldehyde compound or a ketone compound from a primary or secondary alcohol at a higher temperature than that in case of a conventional method, within a short time and with a high yield.

The above object can be achieved by the method of the present invention.

The method of the present invention, for producing an aldehyde compound or a ketone compound using a microreactor, comprises a step (1) of mixing a liquid containing a sulfoxide compound with a liquid containing an activating agent for the sulfoxide compound to allow them to react with each other and to produce an activation reaction product of the sulfoxide compound; a step (2) of mixing the liquid containing the activation reaction product of the sulfoxide compound with a liquid containing at least one member selected from primary and secondary alcohols to allow them to react to each other and to prepare a liquid containing an alkoxysulfonium salt; and a step (3) of mixing the resulting liquid containing an alkoxysulfonium salt with a basic compound-containing liquid and to allow them to react with each other and to prepare a liquid containing an aldehyde compound or a ketone compound corresponding to the alkyl alcohol, wherein at least one step of the steps (1), (2) and (3) is carried out using a microreactor.

In the method of the present invention, the microreactor preferably comprises two liquid-introducing channels having a fine cross-sectional profile for introducing two type of liquids; one micromixer portion, for mixing and reacting the two kinds of introduced liquids with each other, having a fine cross-sectional profile and connected to the liquid introducing channel; and one liquid discharging channel for discharging a reaction product liquid from the micromixer portion,

having a fine cross-sectional profile.

5 In the method of the present invention, preferably, two steps connected to each other are carried out by using a microreactor and a liquid discharging channel of a reactor of an upstream step and a liquid introducing channel of a reactor of a downstream step connected to the upstream step, are connected with each other through a connecting capillary tube.

10 In the method of the present invention, the steps (1) and (2) are preferably carried out in the microreactor.

15 In the method of the present invention, the temperatures of the liquids in the micromixer portion and the liquid discharging channel of the microreactor are preferably adjusted to a desired values.

In the method of the present invention, the temperature of the liquids in the connecting capillary tube is preferably adjusted to a desired value.

20 In the method of the present invention, preferably, the cross-sectional area of the liquid introducing channel, that of the liquid micromixer portion and that of the liquid discharging channel in the microreactor, are respectively $0.7 \mu\text{m}^2$ to 1 mm^2 , $0.7 \mu\text{m}^2$ to 1 mm^2 and $0.7 \mu\text{m}^2$ to 1 mm^2 .

25 In the method of the present invention, a major diameter/minor diameter ratio of the cross section of the liquid introducing channel, the liquid micromixer portion and the liquid discharging channel in the microreactor, is preferably 1 or more and the minor diameter is preferably within a range from $1 \mu\text{m}$ to 1 mm .

30 In the method of the present invention, preferably, in the microreactor, the flow rate of the liquid to be discharged from the liquid micromixer is adjusted so that two kinds of liquids mixed with each other can be reacted to each other in the microreactor with a desired mixing efficiency and a desired retention time.

In the method of the present invention, the residence time of the liquid in the microreactor is preferably adjusted within a range from 0.001 to 60 seconds.

5 In the method of the present invention, preferably, step (1) is carried out using a microreactor and the residence time of a mixed reaction solution of the sulfoxide compound-containing liquid with an activating agent-containing liquid in a portion of the microreactor
10 between the inlet of the micromixer portion and the inlet of the reactor for the step (2) is in the range of from 0.001 to 60 seconds.

 In the method of the present invention, preferably, step (1) is carried out in the microreactor and the
15 reaction temperature in step (1) is in the range of from -80 to +50°C, more preferably from -30 to +40°C.

 In the method of the present invention, preferably, the step (2) is carried out in the microreactor and the mixing reaction temperature in the step (2) is in the
20 range of from -80 to +50°C, more preferably from -30 to +40°C.

 In the method of the present invention, the sulfoxide compound is preferably selected from a dialkyl sulfoxide.

25 In the method of the present invention, dimethyl sulfoxide is preferably used as a dialkyl sulfoxide.

 In the method of the present invention, the activating agent for a sulfoxide compound is preferably selected from acetic anhydride, oxalyl chloride,
30 trifluoroacetic anhydride, trifluoromethanesulfonic anhydride, diphosphorus pentaoxide, chlorine, benzoyl chloride, acetyl chloride, methanesulfonyl chloride, p-toluenesulfonyl chloride, sulfur trioxide-pyridine complex and 2,4,6-trichloro-1,3,5-triazine.

35 In the method of the present invention, the primary and secondary alcohols are preferably selected from

saturated and unsaturated C₁-C₂₀ aliphatic primary and secondary alcohols, or saturated and unsaturated aliphatic primary and secondary alcohols having an alicyclic aromatic hydrocarbon group, and saturated and
5 unsaturated primary and secondary alcohols having a heterocyclic group.

In the method of the present invention, the basic compound is preferably selected from organic amine compounds.

10 In the method of the present invention, the organic amine compound is preferably selected from trialkylamines.

In the method of the present invention, a molar ratio of the sulfoxide compound to be supplied to the
15 first step to the primary or secondary alcohol to be supplied to the second step is preferably within a range of from 1:1 to 20:1.

In the method of the present invention, a molar ratio of the activating agent for a sulfoxide compound to
20 be supplied to the first step to the primary or secondary alcohol to be supplied to the second step is preferably within a range of from 1:1 to 2:1.

In the method of the present invention, a molar amount of the base compound to be supplied to the third
25 step is preferably 2 to 20 times the molar amount of the primary or secondary alcohol to be supplied to the second step.

The method of the present invention may further comprise a step of isolating the target aldehyde or
30 ketone compound from the aldehyde or ketone compound-containing liquid prepared in the step (3).

When an aldehyde compound or a ketone compound is produced from a corresponding primary or secondary alcohol in accordance with the method of the present
35 invention, the use of a microreactor in at least one step of the method enables a relatively high temperature of, for example, about 20°C to be used in place of a low

temperature of -50°C used in the conventional method, and the target compound to be produced at a high yield within a short time.

5 BEST MODE FOR CARRYING OUT THE INVENTION

The method for producing a corresponding aldehyde compound or a corresponding ketone compound by using a microreactor comprises:

10 a step (1) of mixing a liquid containing a sulfoxide compound with a liquid containing an activating agent for the sulfoxide compound to allow them to react with each other and to produce an activation reaction product of the sulfoxide compound;

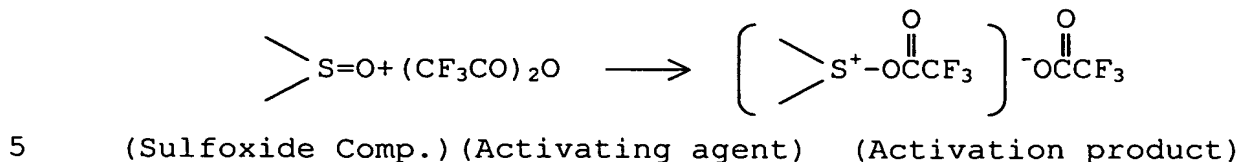
15 a step (2) of mixing the liquid containing the activation reaction product of the sulfoxide compound with a liquid containing at least one member selected from primary and secondary alcohols to allow them to react with each other and to prepare a liquid containing an alkoxysulfonium salt; and

20 a step (3) of mixing the resulting liquid containing an alkoxysulfonium salt with a basic compound-containing liquid to allow them to react with each other and to prepare a liquid containing an aldehyde compound or a ketone compound corresponding to the alkyl alcohol,
25 wherein at least one step of the steps (1), (2) and (3) is carried out by using a microreactor.

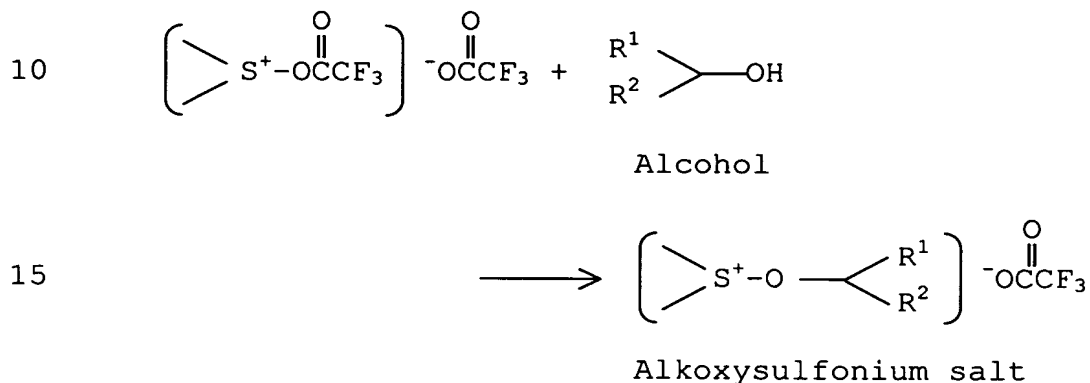
The microreactor is preferably used in at least two of steps (1), (2) and (3), more preferably in the steps (1) and (2), and still more preferably in the three steps
30 (1), (2) and (3).

The steps (1), (2) and (3) of the method of the present invention are carried out according to the following reaction scheme (1):

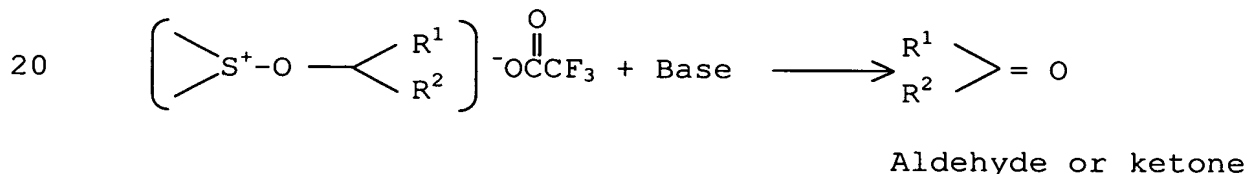
Step (1)



Step (2)



Step (3)



25 In the formulae, R^1 and R^2 respectively and independently from each other represent a hydrocarbon group or a heterocyclic organic group, R^1 and R^2 may be combined with each other to form a cyclic group, or one of R^1 and R^2 represents a hydrocarbon group or a heterocyclic organic group and the other one represents a

30 hydrogen atom.

The structure of the microreactor usable for the method of the present invention is not specifically limited, but the microreactor preferably comprises two liquid-introducing channels for introducing two kinds of liquids having a fine cross-sectional profile; one

35 micromixer portion, for mixing and reacting two kinds of liquids introduced, having a fine cross-sectional profile and connected to the liquid-introducing channel; and one

liquid discharging channel for discharging the resultant reaction product liquid from the micromixer portion, having a fine cross-sectional profile.

5 In the micromixer portion as mentioned above, two kinds of liquids are uniformly mixed with each other and in the micromixer portion and the liquid discharging channel the temperature of the mixed liquid is adjusted to a desired temperature.

10 In the method of the present invention, in the case where two steps connected to each other are carried out by using microreactors, a liquid-discharging channel of a reactor of the upstream step and a liquid-discharging channel of a reactor of the downstream step are preferably connected with each other through a connecting
15 capillary tube. The temperature of the liquid mixture obtained by uniform mixing in the micromixer can be adjusted to a desired temperature in the micromixer and the liquid-discharging channel and also the desired reaction can be allowed to proceed and complete. The
20 connecting capillary tube is preferably provided with means for adjusting the temperature of the liquid which flows through the connecting capillary tube. The means may be a constant temperature bath, a temperature control jacket or the like.

25 In the method of the present invention, as described above, as described above, the microreactor is preferably used in at least the two steps (1) and (2). Thereby, main reaction steps (1) and (2) of the method of the present invention can be accurately controlled and the
30 respective reactions can be completed within a reduced time and with high efficiency.

35 In the microreactor used in the method of the present invention, the areas of the cross-sections of the liquid-introducing channel, the liquid micromixer portion and the liquid-discharging channel are respectively and preferably from $0.7 \mu\text{m}^2$ to 1 mm^2 (more preferably from 0.007 to 0.7 mm^2), $0.7 \mu\text{m}^2$ to 1 mm^2 (more preferably from

0.007 to 0.7 mm²) and 0.7 μm² to 1 mm² (more preferably from 0.007 to 0.7 mm²), and the major diameter/minor diameter ratios of the cross sections are preferably 1 or more and the minor diameters of the cross-sections are preferably within a range from 1 μm to 1 mm, and more preferably from 25 to 500 μm.

In the microreactor used in the method of the present invention, the flow rate of the liquid to be discharged from the liquid micromixer is defined so as to react two kinds of liquids mixed in the microreactor with a desired mixing efficiency and a desired residence time.

In the method of the present invention, each reaction time in the reactions (1), (2) and (3) can be appropriately adjusted, but the residence time of the liquid in the microreactor is preferably adjusted to within a range of from 0.001 to 60 seconds. In the method of the present invention, the step (1) is preferably carried out in the microreactor and the mixing reaction temperature is preferably from -30 to +50°C, and also the step (2) is preferably carried out in the microreactor and the mixing reaction temperature is preferably from -80 to +50°C, and more preferably from -30 to +40°C.

In the method of the present invention, in case of the step of using no microreactor, a reactor comprising two liquid supply means and one product liquid discharging means, for example, a T joint type reactor can be used. The reactor is preferably provided with temperature-adjusting means, liquid flow rate-adjusting means, etc.

The sulfoxide compound to be supplied to the step (1) of the method of the present invention is preferably selected from a dialkyl sulfoxide and, more preferably, dimethyl sulfoxide is used. As the liquid containing a sulfoxide compound, an organic solvent solution of the sulfoxide compound is usually used. If the sulfoxide

compound is liquid, it can be used at it is.

The organic solvent is not specifically limited as far as it is a solvent which has hitherto been in the Swern oxidation reaction, and examples thereof include
5 chlorinated hydrocarbons such as methylene chloride, 1,2-dichloroethane, chlorobenzene and 1,2-dichlorobenzene; aromatic hydrocarbons such as benzene, toluene and xylene; ethers such as diethyl ether, diisopropyl ether, dibutyl ether, dimethoxyethane, tetrahydrofuran and
10 dioxane; saturated hydrocarbons such as pentane, hexane, heptane, octane and cyclohexane; and acetonitrile, propionitrile and hexamethylphosphoramide (HMPA). Preferably, methylene chloride, toluene and chlorobenzene are used.

15 The concentration of the sulfoxide compound in the liquid containing a sulfoxide compound is preferably from 0.1 to 20 mol/liter.

The activating agent for a sulfoxide compound to be used in the step (1) of the method of the present
20 invention is preferably selected from acetic anhydride, oxalyl chloride, trifluoroacetic anhydride, trifluoromethanesulfonic anhydride, diphosphorus pentaoxide, chlorine, benzoyl chloride, acetyl chloride, methanesulfonyl chloride, p-toluenesulfonyl chloride,
25 sulfur trioxide-pyridine complex and 2,4,6-trichloro-1,3,5-triazine and, more preferably, trifluoroacetic anhydride and oxalyl chloride are used. The activating agent-containing liquid can be prepared by dissolving an activating agent in an organic solvent. This organic
30 solvent is preferably the same as the organic solvent for a sulfoxide compound. The concentration of the activating agent in the activating agent-containing liquid is preferably from 0.1 to 15 mol/liter.

In the step (1) of the method of the present
35 invention, as shown in the step (1) of the reaction scheme (1), a sulfoxide compound is reacted with an activating agent (for example, trifluoroacetic anhydride)

to produce an activation reaction product of the sulfoxide compound. The activation reaction product produced in the step (1) is unstable and exhibits the following tendency. Namely, at the temperature of -30°C or higher, Pummerer rearrangement occurs on the activation reaction product to cause the activation reaction product to be decomposed into $\text{CH}_3\text{S}^+ = \text{CH}_2$ and $\text{CF}_3\text{CO}_2\text{H}$ and, furthermore decomposition products to produce $\text{CH}_3\text{SCH}_2\text{OC}(\text{O})\text{CF}_3$, or in the step (2), the decomposition reaction product reacts with a primary or secondary alcohol to produce $\text{R}^1(\text{R}^2)\text{-OCH}_2\text{SCH}_3$ (MTM ether), and in the step (3), $\text{CH}_3\text{SCH}_2\text{OC}(\text{O})\text{CF}_3$ reacts with a base to produce $\text{R}^1(\text{R}^2)\text{-OC}(\text{O})\text{CF}_3$ (TFA ester). When the reaction in the step (1) is completed by vigorous mixing using a microreactor and accurately control at a predetermined temperature, it becomes possible to prevent or reduce the Pummerer rearrangement and to feed an activation reaction product-containing liquid into the step (2).

In step (2) of the method of the present invention, the activation reaction product-containing liquid introduced from the step (1) and a liquid containing at least one of primary and secondary alcohols are mixed and reacted to prepare a liquid containing an alkoxysulfonium salt shown in the step (2) of the reaction scheme (1).

The primary and secondary alcohols to be used in the step (2) of the method of the present invention are not noticeably limited as far as they are a primary alcohol and a secondary alcohol (which have an OH group combined with carbon atoms of an aliphatic hydrocarbon group but not with carbon atoms constituting an aromatic ring (namely not a phenolic OH group)). The primary and secondary alcohols include the followings:

(1) $\text{C}_1\text{-C}_{20}$ Saturated and unsaturated aliphatic primary alcohols, for example, methyl alcohol, ethyl alcohol, n-propyl alcohol, butyl alcohol, isobutyl alcohol, pentyl alcohol, isopentyl alcohol, neopentyl alcohol, hexyl alcohol, isohexyl

alcohol, heptyl alcohol, octyl alcohol, 2-ethylhexyl alcohol, nonyl alcohol, decyl alcohol, allyl alcohol, crotyl alcohol, propargyl alcohol, geraniol and phytol;

5 (2) alicyclic primary alcohols in which an -OH group is combined with carbon atoms of a C₁-C₁₂ alicyclic hydrocarbon ring via a linear hydrocarbon group having one or more carbon atoms, for example, cyclohexylmethyl alcohol, 2-norbornane methanol and 5-norbornene-2-methanol;

10 (3) aromatic primary alcohols in which an -OH group is combined with carbon atoms of an aromatic hydrocarbon ring via an alicyclic hydrocarbon group having one or more carbon atoms, for example, benzyl alcohol, phenethyl alcohol, cinnamyl alcohol, 15 salicyl alcohol and 2-phenyl ethanol;

(4) heterocyclic primary alcohols in which an -OH group is combined with carbon atoms of a heterocyclic group via a C₁ linear hydrocarbon group having one or more carbon atoms, for example, 20 furfuryl alcohol;

(5) C₃-C₂₀ saturated and unsaturated aliphatic secondary alcohols, for example, 2-propanol, 2-butanol, 2-pentanol, 3-pentanol, 2-hexanol, 3-hexanol, 2-heptanol, 3-heptanol, 4-heptanol, 2- 25 octanol, 3-octanol, 4-octanol, 2-nonanol, 3-nonanol, 4-nonanol and 5-nonanol;

(6) C₃-C₂₀ alicyclic secondary alcohols, for example, cyclopentanol, 2-methylcyclopentanol, 3- 30 methylcyclopentanol, 2-ethylcyclopentanol, 3-ethylcyclopentanol, 2-n-propylcyclopentanol, 3-n-propylcyclopentanol, 2-isopropylcyclopentanol, 3-isopropylcyclopentanol, 2-n-butylcyclopentanol, 3-n-butylcyclopentanol, 2-isobutylcyclopentanol, 3- 35 isobutylcyclopentanol, 2-sec-butylcyclopentanol, 3-sec-butylcyclopentanol, 2-tert-butylcyclopentanol, 3-tert-butylcyclopentanol; cyclohexanol, 2-methylcyclohexanol,

3-methylcyclohexanol, 4-methylcyclohexanol, 2-ethylcyclohexanol, 3-ethylcyclohexanol, 4-ethylcyclohexanol, 2-n-propylcyclohexanol, 3-n-propylcyclohexanol, 4-n-propylcyclohexanol, 2-
5 isopropylcyclohexanol, 3-isopropylcyclohexanol, 4-isopropylcyclohexanol, 2-n-butylcyclohexanol, 3-n-butylcyclohexanol, 4-n-butylcyclohexanol, 2-isobutylcyclohexanol, 3-isobutylcyclohexanol, 4-isobutylcyclohexanol, 2-sec-butylcyclohexanol, 3-sec-
10 butylcyclohexanol, 4-sec-butylcyclohexanol, 2-tert-butylcyclohexanol, 3-tert-butylcyclohexanol, 4-tert-butylcyclohexanol; cycloheptanol, 2-methylcycloheptanol, 3-methylcycloheptanol, 4-methylcycloheptanol, 2-ethylcycloheptanol, 3-ethylcycloheptanol, 4-
15 ethylcycloheptanol, 2-n-propylcycloheptanol, 3-n-propylcycloheptanol, 4-n-propylcycloheptanol, 2-isopropylcycloheptanol, 3-isopropylcycloheptanol, 4-isopropylcycloheptanol, 2-n-butylcycloheptanol, 3-n-butylcycloheptanol, 4-n-butylcycloheptanol, 2-
20 isobutylcycloheptanol, 3-isobutylcycloheptanol, 4-isobutylcycloheptanol, 2-sec-butylcycloheptanol, 3-sec-butylcycloheptanol, 4-sec-butylcycloheptanol, 2-tert-butylcycloheptanol, 3-tert-butylcycloheptanol, 4-tert-butylcycloheptanol; cyclooctanol, 2-methylcyclooctanol, 3-methylcyclooctanol, 4-methylcyclooctanol, 5-
25 methylcyclooctanol, 2-ethylcyclooctanol, 3-ethylcyclooctanol, 4-ethylcyclooctanol, 5-ethylcyclooctanol, 2-n-propylcyclooctanol, 3-n-propylcyclooctanol, 4-n-propylcyclooctanol, 5-n-propylcyclooctanol, 2-isopropylcyclooctanol, 3-isopropylcyclooctanol, 4-isopropylcyclooctanol, 5-isopropylcyclooctanol, 2-n-butylcyclooctanol, 3-n-butylcyclooctanol, 4-n-butylcyclooctanol, 5-n-butylcyclooctanol, 2-isobutylcyclooctanol, 3-isobutylcyclooctanol, 4-isobutylcyclooctanol, 5-isobutylcyclooctanol, 2-sec-butylcyclooctanol, 3-sec-butylcyclooctanol, 4-sec-butylcyclooctanol, 5-sec-

butylcyclooctanol, 2-tert-butylcyclooctanol, 3-tert-butylcyclooctanol, 4-tert-butylcyclooctanol, 5-tert-butylcyclooctanol; decahydro-1-naphthol, decahydro-2-naphthol, norborneol and isoborneol.

5 In the step (2) of the method of the present invention, when a solid is formed by the reaction of the primary alcohol or secondary alcohol at the reaction temperature in the step (2), the solid is used after dissolving it in the same organic solvent as the organic
10 solvent for the step (1). The concentration of the alcohol is preferably from 0.1 to 15 mol/liter.

 When the step (2) of the method of the present invention is carried out in the microreactor, a rearrangement reaction of the alkoxysulfonium salt shown
15 in the formula (1) is prevented or reduced and the resulting alkoxysulfonium salt-containing liquid can be fed into the step (3).

 In the step (3) of the method of the present invention, the alkoxysulfonium salt-containing liquid is
20 mixed with a basic compound-containing liquid and they are reacted with each other to prepare a liquid containing an aldehyde or ketone compound corresponding to the primary or secondary alcohol.

 The basic compound is preferably selected from an
25 organic amine compound, for example, alkylamine compound, triethylamine, tripropylamine, tributylamine, diethylmethylaniline, diethylcyclohexylaniline and diisopropylamine, more preferably selected from a trialkylamine and, still more preferably, trimethylamine
30 is used. When the basic compound to be used cannot be in a liquid form at the reaction temperature of the step (3), it can be used after dissolving in the same solvent as the organic solvent used in the step (1). The concentration of the basic compound is preferably from
35 0.1 to 20 mol/liter.

 The mixing and reaction temperature in the step (3) is preferably from -30 to +40°C, and more preferably from

0 to +40°C, while the residence time is preferably from 1 second to 5 hours, and more preferably from 10 minutes to 1 hour.

5 The aldehyde or ketone compound-containing liquid prepared in the step (3) is discharged from the step (3) and, if necessary, this liquid is subjected to an isolation step for the target compound, for example, a step such as an extraction, distillation, crystallization or silica gel column chromatography step.

10 In the method of the present invention, a molar ratio of the sulfonyl compound to be supplied to step (1) to the primary or secondary alcohol to be supplied to step (2) is preferably within a range from 1:1 to 20:1, and more preferably from 1.1:1 to 3:1. When the molar
15 ratio is less than 1:1, there may arise a problem such as left-over unreacted primary or secondary alcohol. On the other hand, when the molar ratio is more than 20:1, an operation of isolating an excess sulfonyl compound becomes complicated and there may arise industrial and
20 economical problems.

 When step (1) is carried out using a microreactor, the residence time of a mixed reaction solution of a sulfoxide compound-containing liquid and an activating agent-containing liquid from an inlet of a micromixer
25 portion to an inlet of a reactor for the step (2) is preferably from 0.001 to 60 seconds, and more preferably from 0.01 to 3 seconds.

 In the method of the present invention, a molar ratio of the sulfonyl compound activating agent to be
30 supplied in step (1) to the primary or secondary alcohol to be supplied in the step (2) is preferably within a range from 1:1 to 2:1, and more preferably from 1.1:1 to 1.5:1. When the molar ratio is less than 1:1, there may arise a problem such as left-over unreacted primary or
35 secondary alcohol. On the other hand, when the molar ratio is more than 2:1, there may arise a problem that the amount of by-products increase.

A molar amount of the basic compound to be supplied to the step (3) of the method of the present invention is preferably 2 to 20 times, and more preferably 2.5 to 6 times, the molar amount of the primary or secondary alcohol. When the molar amount of the basic compound is less than 2 times as that of the primary or secondary alcohol, the efficiency of the reaction of converting of the alkoxysulfonium salt into an aldehyde or ketone may become insufficient. On the other hand, when the molar amount of the basic compound is more than 20 times as that of the primary or secondary alcohol, there may arise industrial and economical problems.

The aldehyde compound or ketone compound obtained by the method of the present invention corresponds to the primary alcohol or secondary alcohol used as a starting material. The following compounds can be produced by the method of the present invention:

- (1) aldehydes, for example,
saturated aliphatic aldehyde [for example, formaldehyde, acetoaldehyde, propionaldehyde, butylaldehyde, hexanal, higher aldehyde (octaaldehyde, nonaaldehyde, etc.)],
unsaturated aliphatic aldehyde (for example, acrolein, etc.), glyoxal, methyl glyoxal, aliphatic polyaldehyde (for example, malonaldehyde, succinaldehyde, glutaraldehyde, adipinaldehyde, pimelic aldehyde, suberinaldehyde, sebacic aldehyde, etc.), aliphatic aldehyde such as aminoacetoaldehyde; aromatic aldehyde such as benzaldehyde, oxybenzaldehyde, nitrobenzaldehyde, aminobenzaldehyde, cinnamaldehyde, salicylaldehyde, anisaldehyde, 1-naphthylacetoaldehyde, vanillin (vanillaldehyde), phthalaldehyde or isophthalaldehyde, terephthalaldehyde; alicyclic aldehyde such as formylcyclohexane, citronellal or citral; heterocyclic aldehyde such as nicotinaldehyde or furfural; and
- (2) ketones, for example,
aliphatic ketone such as acetone, methyl ethyl ketone, diethyl ketone, dipropyl ketone, methyl propyl ketone,

methyl butyl ketone or pinacolone; alicyclic ketone (cyclic ketone) such as cyclopentanone, cyclohexanone, cyclooctanone, 2-methylcyclohexanone, 2-ethylcyclohexanone, 2,6-dimethylcyclohexanone, 4-chlorocyclohexanone, 4-methoxycyclohexanone, menthone or camphor; aromatic ketone such as acetophenone, propiophenone, benzophenone, deoxybenzoin or 1-naphthalenone; and heterocyclic ketone such as inden-1-one, 1,2,3-indanetrione, fluoren-9-one or 4-pyranone.

These aldehyde compounds and ketone compounds are useful in the fields of organic compound drugs and pesticides.

EXAMPLES

The method of the present invention will now be described in more detail by way of the following examples.

Example 1

In the production of cyclohexanone from cyclohexanol by the method of the present invention, the steps (1), (2) and (3) were carried out using the following reactor.

Step (1)

A microreactor (manufactured by IMM GmbH, Single Mixer Ver. 2, Inlay: Ag plating, fine liquid introducing channel width: 40 μ m) was used.

To each of two channels for respectively introducing a sulfoxide-containing liquid and an activating agent-containing liquid for the sulfoxide compound, introducing channel, a SUS tube (inner diameter: 1.0 mm, length: 20 cm) was connected, and the each channel was connected to a liquid supply source through the SUS tube.

Step (2)

A microreactor (the same as that for the step (1)) was used. A reaction product liquid discharging channel of the microreactor of the step (1) was connected to a reaction product solution-introducing channel of the microreactor of the step (2) through a connecting SUS

tube (inner diameter: 0.1 mm, length: 3.2 cm), and then an alcohol supply source was connected to an alcohol-introducing channel of a microreactor for the step (2) through a SUS tube (inner diameter: 1.0 mm, length: 20 cm).

Step (3)

A microreactor (the same as the microreactor for the step (1)) was used.

A reaction product solution-discharging channel of the microreactor of step (2) was connected to a reaction product solution-introducing channel for the step (3) through a connecting SUS tube (inner diameter: 1.0 mm, length: 10 cm). Also, a basic compound-introducing channel of a microreactor for the step (3) was connected to a basic compound-supply source through SUS tube (inner diameter: 1.0 mm, length: 20 cm) and then a reaction product solution-discharging SUS tube (inner diameter: 1.0 mm, length: 20 cm) was connected to a reaction product solution-discharging channel.

The microreactors for the steps (1), (2) and (3) and the SUS tubes connected thereto were dipped in a constant low-temperature bath set at a constant temperature of -20°C . To the end of the SUS tube for discharging a reaction product solution of the microreactor for the step (3), a SUS tube (inner diameter: 1.0 mm, length: 100 cm) was connected through a connecting tube (inner diameter: 1 mm, length: 50 cm) made of PTFE (polytetrafluoroethylene), and then only the connecting tube was dipped in a water bath at a temperature of 30°C .

By using a gas-tight syringe, a dimethyl sulfoxide/methylene chloride solution having a concentration of 4.0 mol/liter and a trifluoroacetic anhydride (TFAA)/methylene chloride solution having a concentration of 3.0 mol/liter were respectively fed into the microreactor, for step (1), at a flow rate of 1.0 ml/min. Immediately after the reaction mixture solution was retained in the reactor for 0.01 seconds, the

resultant reaction product solution was fed into the microreactor for the step (2) and, at the same time, a cyclohexanol/methylene chloride solution having a concentration of 1.0 mol/liter was fed into the microreactor for the step (2) at a flow rate of 2.0 ml/min. Immediately after the reaction mixture solution was retained in the reactor for the step (2) for 1.2 seconds, the resultant reaction product solution was fed into the microreactor for the step (3) and, at the same time, a triethylamine/methylene chloride solution having a concentration of 1.4 mol/liter was fed at a flow rate of 4.0 ml/min into the reactor. After the above reaction operation was carried out for 4 minutes, the resultant reaction product solution discharged from the microreactor for the step (3) was collected in a sample bottle containing an internal standard substance for one minute.

The amount of TFAA employed in the step (1) was 1.5 equivalents, the reaction temperature of the step (1) was -20°C, and the reaction time was 0.01 seconds.

The contents of the collected compounds in the reaction product solution were determined by a gas chromatograph internal standard method. The results are shown below.

Cyclohexanone	78%
Cyclohexyl trifluoroacetate	5%
Cyclohexyl methylthiomethyl ether	3%
Cyclohexanol	10%

Example 2

In the production of cyclohexanone from cyclohexanol by the method of the present invention, the steps (1), (2) and (3) were carried out using the following reactor. Step (1)

A microreactor (manufactured by IMM GmbH, Single Mixer Ver. 2, Inlay: Ag plating, fine liquid introducing channel width: 40 µm) was used.

To each of two introduction channels for sulfoxide-

containing liquid and activating agent-containing liquid for the sulfoxide compound, a SUS tube (inner diameter: 1.0 mm, length: 20 cm) was connected, and the each channel was connected to a liquid supply source through the SUS tube.

Step (2)

A microreactor (the same as that for the step (1)) was used. A reaction product liquid discharging channel of the microreactor of the step (1) was connected to a reaction product solution introducing channel of a microreactor of the step (2) through a connecting SUS tube (inner diameter: 0.25 mm, length: 3.2 cm), and then an alcohol supply source was connected to an alcohol introducing channel of a microreactor for the step (2) through a SUS tube (inner diameter: 1.0 mm, length: 20 cm).

Step (3)

A microreactor (the same as the microreactor for step (1)) was used. A reaction product solution-discharging channel of the microreactor of the step (2) was connected to a reaction product solution-introducing channel for the step (3) through a connecting SUS tube (inner diameter: 1.0 mm, length: 10 cm). Also, a basic compound-introducing channel of a microreactor for the step (3) was connected to a basic compound supply source through a SUS tube (inner diameter: 1.0 mm, length: 20 cm) and then a reaction product solution-discharging SUS tube (inner diameter: 1.0 mm, length: 20 cm) was connected to a reaction product solution-discharging channel.

The microreactors for the steps (1), (2) and (3) and the SUS tubes connected thereto were dipped in a constant low-temperature bath set at a constant temperature of -20°C . To the end of the SUS tube for discharging a reaction product solution of the microreactor for the step (3), a SUS tube (inner diameter: 1.0 mm, length: 100 cm) was connected through a connecting tube (inner

diameter: 1 mm, length: 50 cm) made of PTFE (polytetrafluoroethylene), and then only the connecting tube was dipped in a water bath at a temperature of 30°C.

By using a gas-tight syringe, a dimethyl
5 sulfoxide/methylene chloride solution having a concentration of 4.0 mol/liter and a trifluoroacetic anhydride (TFAA)/methylene chloride solution having a concentration of 3.0 mol/liter were respectively fed into the microreactor for the step (1) at a flow rate of 1.0
10 ml/min. Immediately after the reaction mixture solution was retained for 0.05 seconds, the reaction product solution was fed into the microreactor for the step (2) and, at the same time, a cyclohexanol/methylene chloride solution having a concentration of 1.0 mol/liter was fed
15 into the microreactor for the step (2) at a flow rate of 2.0 ml/min. Immediately after the reaction mixture solution was retained for 1.2 seconds, the reaction product solution was fed into the microreactor for step (3) and, at the same time, a triethylamine/methylene
20 chloride solution having a concentration of 1.4 mol/liter was fed at a flow rate of 4.0 ml/min. After the above reaction operation was carried out for 4 minutes, the reaction product solution discharged from the microreactor for the step (3) was collected in a sample
25 bottle, containing an internal standard substance, for one minute.

The amount of TFAA employed in the step (1) was 1.5 equivalents, the reaction temperature of the step (1) was -20°C, and the reaction time was 0.05 seconds.

30 The contents of the collected compounds in the reaction product solution were determined by a gas chromatograph internal standard method. The results are shown below.

	Cyclohexanone	66%
35	Cyclohexyl trifluoroacetate	6%
	Cyclohexyl methylthiomethyl ether	5%
	Cyclohexanol	21%

Example 3

In the production of cyclohexanone from cyclohexanol by the method of the present invention, the steps (1), (2) and (3) were carried out using the following reactor.

5 Step (1)

A microreactor (manufactured by IMM GmbH, Single Mixer Ver. 2, Inlay: Ag plating, fine liquid introducing channel width: 40 μ m) was used.

10 To each of two introduction channels for a sulfoxide-containing liquid and an activating agent-containing liquid for the sulfoxide compound, a SUS tube (inner diameter: 1.0 mm, length: 20 cm) was connected, and each channel was connected to a liquid supply source through the SUS tube.

15 Step (2)

A microreactor (the same as that for the step (1)) was used. A reaction product liquid discharging channel of the microreactor of the step (1) was connected to a reaction product solution-introducing channel of a
20 microreactor of the step (2) through a connecting SUS tube (inner diameter: 1.0 mm, length: 10 cm), and then an alcohol supply source was connected to an alcohol introducing channel of a microreactor for the step (2) through a SUS tube (inner diameter: 1.0 mm, length: 20
25 cm).

Step (3)

A microreactor (the same as the microreactor for step (1)) was used.

A reaction product solution discharging channel of
30 the microreactor of the step (2) was connected to a reaction product solution-introducing channel for the step (3) through a connecting SUS tube (inner diameter: 1.0 mm, length: 10 cm). Also, a basic compound-introducing channel of a microreactor for the step (3)
35 was connected to a basic compound supply source through a SUS tube (inner diameter: 1.0 mm, length: 20 cm) and then a reaction product solution-discharging SUS tube (inner

diameter: 1.0 mm, length: 20 cm) was connected to a reaction product solution discharging channel.

The microreactors for the steps (1), (2) and (3) and the SUS tubes connected thereto were dipped in a constant low temperature bath set at a temperature of -20°C. To the end of the SUS tube for discharging a reaction product solution of the microreactor for the step (3), a SUS tube (inner diameter: 1.0 mm, length: 100 cm) was connected through a connecting tube (inner diameter: 1 mm, length: 50 cm) made of PTFE (polytetrafluoroethylene), and then only the connecting tube was dipped in a water bath at a temperature of 30°C.

By using a gas-tight syringe, a dimethyl sulfoxide/methylene chloride solution having a concentration of 4.0 mol/liter and a trifluoroacetic anhydride (TFAA)/methylene chloride solution having a concentration of 3.0 mol/liter were respectively fed into the microreactor for the step (1) at a flow rate of 1.0 ml/min. Immediately after the reaction mixture solution was retained for 2.4 seconds, the reaction product solution was fed into the microreactor for the step (2) and, at the same time, a cyclohexanol/methylene chloride solution having a concentration of 1.0 mol/liter was fed into the microreactor for the step (2) at a flow rate of 2.0 ml/min. Immediately after the reaction mixture solution was retained for 1.2 seconds, the reaction product solution was fed into the microreactor for the step (3) and, at the same time, a triethylamine/methylene chloride solution having a concentration of 1.4 mol/liter was fed at a flow rate of 4.0 ml/min. After the above reaction operation was carried out for 4 minutes, the resultant reaction product solution discharged from the microreactor for the step (3) was collected in a sample bottle containing an internal standard substance for one minute.

The amount of TFAA employed in the step (1) was 1.5 equivalents, the reaction temperature of the step (1) was

-20°C, and the reaction time was 2.4 seconds.

The contents of the collected compounds in the reaction product solution were determined by a gas chromatograph internal standard method. The results are shown below.

Cyclohexanone	66%
Cyclohexyl trifluoroacetate	6%
Cyclohexyl methylthiomethyl ether	5%
Cyclohexanol	18%

Example 4

In the production of cyclohexanone from cyclohexanol by the method of the present invention, the steps (1), (2) and (3) were carried out using the following reactor. Step (1)

A microreactor (manufactured by IMM GmbH, Single Mixer Ver. 2, Inlay: Ag plating, fine liquid introducing channel width: 40 μ m) was used.

To each of two introduction channels for a sulfoxide-containing liquid and an activating agent-containing liquid for the sulfoxide compound, a SUS tube (inner diameter: 1.0 mm, length: 20 cm) was connected, and each channel was connected to a liquid supply source through the SUS tube.

Step (2)

A microreactor (the same as that for the step (1)) was used. A reaction product liquid discharging channel of the microreactor of the step (1) was connected to a reaction product solution introducing channel of a microreactor of the step (2) through a connecting SUS tube (inner diameter: 1.0 mm, length: 100 cm), and then an alcohol supply source was connected to an alcohol introducing channel of a microreactor for the step (2) through a SUS tube (inner diameter: 1.0 mm, length: 20 cm).

Step (3)

A microreactor (the same as the microreactor for step (1)) was used.

A reaction product solution discharging channel of the microreactor of the step (2) was connected to a reaction product solution introducing channel for the step (3) through a connecting SUS tube (inner diameter: 1.0 mm, length: 10 cm). Also, a basic compound-introducing channel of a microreactor for the step (3) was connected to a basic compound supply source through a SUS tube (inner diameter: 1.0 mm, length: 20 cm) and then a reaction product solution-discharging SUS tube (inner diameter: 1.0 mm, length: 20 cm) was connected to a reaction product solution discharging channel.

The microreactors for the steps (1), (2) and (3) and the SUS tubes connected thereto were dipped in a constant low temperature bath set at a temperature of -20°C. To the end of the SUS tube for discharging a reaction product solution of the microreactor for the step (3), a SUS tube (inner diameter: 1.0 mm, length: 100 cm) was connected through a connecting tube (inner diameter: 1 mm, length: 50 cm) made of PTFE (polytetrafluoroethylene), and then only the connecting tube was dipped in a water bath at a temperature of 30°C.

By using a gas-tight syringe, a dimethyl sulfoxide/methylene chloride solution having a concentration of 4.0 mol/liter and a trifluoroacetic anhydride (TFAA)/methylene chloride solution having a concentration of 3.0 mol/liter were respectively fed into the microreactor for the step (1) at a flow rate of 1.0 ml/min, through a gas-tight syringe. Immediately after the reaction mixture solution was retained for 24 seconds, the reaction product solution was fed into the microreactor for the step (2) and, at the same time, a cyclohexanol/methylene chloride solution having a concentration of 1.0 mol/liter was fed into the microreactor for the step (2) at a flow rate of 2.0 ml/min. Immediately after the reaction mixture solution was retained for 1.2 seconds, the reaction product solution was fed into the microreactor for the step (3)

and, at the same time, a triethylamine/methylene chloride solution having a concentration of 1.4 mol/liter was fed at a flow rate of 4.0 ml/min. After the above reaction operation was carried out for 4 minutes, the reaction
5 product solution discharged from the microreactor for the step (3) was collected in a sample bottle, containing an internal standard substance, for one minute.

The amount of TFAA employed in the step (1) was 1.5 equivalents, the reaction temperature of the step (1) was
10 -20°C, and the reaction time was 24 seconds.

The contents of the collected compounds in the reaction product solution were determined by a gas chromatograph internal standard method. The results are shown below.

15	Cyclohexanone	70%
	Cyclohexyl trifluoroacetate	5%
	Cyclohexyl methylthiomethyl ether	6%
	Cyclohexanol	15%

Example 5

20 In the production of cyclohexanone from cyclohexanol by the method of the present invention, the steps (1), (2) and (3) were carried out using the following reactor.
Step (1)

A microreactor (manufactured by IMM GmbH, Single
25 Mixer Ver. 2, Inlay: Ag plating, fine liquid introducing channel width: 40 µm) was used.

To each of two introduction channels for a sulfoxide-containing liquid and an activating agent-containing liquid for the sulfoxide compound, a SUS tube
30 (inner diameter: 1.0 mm, length: 20 cm) was connected, and each channel was connected to a liquid supply source through the SUS tube.

Step (2)

A microreactor (the same as that for step (1)) was
35 used. A reaction product liquid discharging channel of the microreactor of the step (1) was connected to a reaction product solution-introducing channel of a

microreactor of the step (2) through a connecting SUS tube (inner diameter: 1.0 mm, length: 10 cm), and then an alcohol supply source was connected to an alcohol-introducing channel of a microreactor for the step (2) through a SUS tube (inner diameter: 1.0 mm, length: 20 cm).

Step (3)

A microreactor (the same as the microreactor for step (1)) was used.

A reaction product solution-discharging channel of a microreactor of the step (2) was connected to a reaction product solution-introducing channel for step (3) through a connecting SUS tube (inner diameter: 1.0 mm, length: 100 cm). Also, a basic compound-introducing channel of a microreactor for step (3) was connected to a basic compound supply source through a SUS tube (inner diameter: 1.0 mm, length: 20 cm) and then a reaction product solution-discharging SUS tube (inner diameter: 1.0 mm, length: 20 cm) was connected to a reaction product solution-discharging channel.

The microreactors for the steps (1), (2) and (3) and the SUS tubes connected thereto were dipped in a constant low temperature bath set at a temperature of -20°C . To the end of the SUS tube for discharging a reaction product solution of the microreactor for the step (3), a SUS tube (inner diameter: 1.0 mm, length: 100 cm) was connected through a connecting tube (inner diameter: 1 mm, length: 50 cm) made of PTFE (polytetrafluoroethylene), and then only the connecting tube was dipped in a water bath at a temperature of 30°C .

By using a gas-tight syringe, a dimethyl sulfoxide/methylene chloride solution having a concentration of 4.0 mol/liter and a trifluoroacetic anhydride (TFAA)/methylene chloride solution having a concentration of 3.0 mol/liter were respectively fed into the microreactor for the step (1) at a flow rate of 1.0 ml/min. Immediately after the reaction mixture solution

was retained for 2.4 seconds, the reaction product solution was fed into the microreactor for the step (2) and, at the same time, a cyclohexanol/methylene chloride solution having a concentration of 1.0 mol/liter was fed into the microreactor for the step (2) at a flow rate of 2.0 ml/min. Immediately after the reaction mixture solution was retained for 12 seconds, the reaction product solution was fed into the microreactor for the step (3) and, at the same time, a triethylamine/methylene chloride solution having a concentration of 1.4 mol/liter was fed at a flow rate of 4.0 ml/min. After the above reaction operation was carried out for 4 minutes, the reaction product solution discharged from the microreactor for the step (3) was collected in a sample bottle, containing an internal standard substance, for one minute.

The amount of TFAA employed in the step (1) was 1.5 equivalents, the reaction temperature of the step (1) was -20°C, and the reaction time was 2.4 seconds.

The contents of the collected compounds in the reaction product solution were determined by a gas chromatograph internal standard method. The results are shown below.

	Cyclohexanone	71%
25	Cyclohexyl trifluoroacetate	5%
	Cyclohexyl methylthiomethyl ether	6%
	Cyclohexanol	15%

Example 6

In the production of cyclohexanone from cyclohexanol by the method of the present invention, the steps (1), (2) and (3) were carried out using the following reactor. Step (1)

T-shaped joint-type reactor (cross-sectional inner diameter: 0.8 mm)

To each of two introduction channels for a sulfoxide-containing liquid and an activating agent-containing liquid for the sulfoxide compound, a SUS tube

(inner diameter: 1.0 mm, length: 20 cm) was connected, and each channel was connected to a liquid supply source, through the SUS tube.

Step (2)

5 A microreactor (manufactured by IMM GmbH, Single Mixer Ver. 2, Inlay: Ag plating, fine liquid-introducing channel width: 40 μ m) was used. A reaction product liquid-discharging channel of the T joint type reactor of the step (1) was connected to a reaction product solution
10 introducing channel of the microreactor of the step (2) through a connecting SUS tube (inner diameter: 1.0 mm, length: 10 cm), and then an alcohol supply source was connected to an alcohol-introducing channel of a
15 microreactor for the step (2) through a SUS tube (inner diameter: 1.0 mm, length: 20 cm).

Step (3)

 A microreactor (the same as the microreactor for step (2)) was used.

20 A reaction product solution-discharging channel of a microreactor of the step (2) was connected to a reaction product solution introducing channel for the step (3) through a connecting SUS tube (inner diameter: 1.0 mm, length: 10 cm). Also, a basic compound introducing
25 channel of a microreactor for the step (3) was connected to a basic compound supply source through a SUS tube (inner diameter: 1.0 mm, length: 20 cm) and then a reaction product solution-discharging SUS tube (inner
30 diameter: 1.0 mm, length: 20 cm) was connected to a reaction product solution-discharging channel.

35 The microreactors for the steps (1), (2) and (3) and the SUS tubes connected thereto were dipped in a constant low temperature bath set at a temperature of -20°C. To the end of the SUS tube for discharging a reaction product solution of the microreactor for the step (3), a
SUS tube (inner diameter: 1.0 mm, length: 100 cm) was connected through a connecting tube (inner diameter: 1 mm, length: 50 cm) made of PTFE

(polytetrafluoroethylene), and then only the connecting tube was dipped in a water bath at a temperature of 30°C.

By using a gas-tight syringe, a dimethyl sulfoxide/methylene chloride solution having a
5 concentration of 4.0 mol/liter and a trifluoroacetic anhydride (TFAA)/methylene chloride solution having a concentration of 3.0 mol/liter were respectively fed into the microreactor for the step (1) at a flow rate of 1.0 ml/min. Immediately after the reaction mixture solution
10 was retained for 2.4 seconds, the reaction product solution was fed into the microreactor for the step (2) and, at the same time, a cyclohexanol/methylene chloride solution having a concentration of 1.0 mol/liter was fed into the microreactor for the step (2) at a flow rate of
15 2.0 ml/min. Immediately after the reaction mixture solution was retained for 1.2 seconds, the reaction product solution was fed into the microreactor for the step (3) and, at the same time, a triethylamine/methylene chloride solution having a concentration of 1.4 mol/liter
20 was fed at a flow rate of 4.0 ml/min. After the above reaction operation was carried out for 4 minutes, the reaction product solution discharged from the microreactor for the step (3) was collected in a sample bottle, containing an internal standard substance, for
25 one minute.

The amount of TFAA employed in the step (1) was 1.5 equivalents, the reaction temperature of the step (1) was -20°C, and the reaction time was 2.4 seconds.

The contents of the collected compounds in the
30 reaction product solution were determined by a gas chromatograph internal standard method. The results are shown below.

	Cyclohexanone	72%
	Cyclohexyl trifluoroacetate	10%
35	Cyclohexyl methylthiomethyl ether	3%
	Cyclohexanol	8%

Example 7

In the production of cyclohexanone from cyclohexanol by the method of the present invention, the steps (1), (2) and (3) were carried out using the following reactors.

5 Step (1)

A microreactor (manufactured by IMM GmbH, Single Mixer Ver. 2, Inlay: Ag plating, fine liquid-introducing channel width: 40 μ m) was used.

10 To each of two introduction channels for a sulfoxide-containing liquid and an activating agent-containing liquid for the sulfoxide compound, a SUS tube (inner diameter: 1.0 mm, length: 20 cm) was connected, and each channel was connected to a liquid supply source through the SUS tube.

15 Step (2)

A T-joint-type reactor (cross-sectional inner diameter: 0.8 mm) was used. A reaction product liquid-discharging channel of the microreactor of the step (1) was connected to a reaction product solution-introducing channel of the microreactor of the step (2) through a connecting SUS tube (inner diameter: 1.0 mm, length: 10 cm), and then an alcohol supply source was connected to an alcohol introducing-channel of a microreactor for step (2) through a SUS tube (inner diameter: 1.0 mm, length: 20 cm).

25 Step (3)

A microreactor (the same as microreactor for step (1)) was used.

30 A reaction product solution-discharging channel of a microreactor of the step (2) was connected to a reaction product solution-introducing channel for the step (3) through a connecting SUS tube (inner diameter: 1.0 mm, length: 10 cm). Also, a basic compound-introducing channel of a microreactor for the step (3) was connected to a basic compound supply source through a SUS tube (inner diameter: 1.0 mm, length: 20 cm) and then a reaction product solution-discharging SUS tube (inner

diameter: 1.0 mm, length: 20 cm) was connected to a reaction product solution-discharging channel.

The microreactors for the steps (1), (2) and (3) and the SUS tubes connected thereto were dipped in a constant low-temperature bath set at a constant temperature of -20°C. To the end of the SUS tube for discharging a reaction product solution of the microreactor for the step (3), a SUS tube (inner diameter: 1.0 mm, length: 100 cm) was connected through a connecting tube (inner diameter: 1 mm, length: 50 cm) made of PTFE (polytetrafluoroethylene), and then only the connecting tube was dipped in a water bath at a temperature of 30°C.

By using a gas-tight syringe, a dimethyl sulfoxide/methylene chloride solution having a concentration of 4.0 mol/liter and a trifluoroacetic anhydride (TFAA)/methylene chloride solution having a concentration of 3.0 mol/liter were respectively fed into the microreactor for the step (1) at a flow rate of 1.0 ml/min. Immediately after the reaction mixture solution was retained for 2.4 seconds, the reaction product solution was fed into the microreactor for the step (2) and, at the same time, a cyclohexanol/methylene chloride solution having a concentration of 1.0 mol/liter was fed into the microreactor for the step (2) at a flow rate of 2.0 ml/min. Immediately after the reaction mixture solution was retained for 1.2 seconds, the reaction product solution was fed into the microreactor for the step (3) and, at the same time, a triethylamine/methylene chloride solution having a concentration of 1.4 mol/liter was fed at a flow rate of 4.0 ml/min. After the above reaction operation was carried out for 4 minutes, the reaction product solution was discharged from the microreactor for the step (3) and was collected in a sample bottle, containing an internal standard substance, for one minute.

The amount of TFAA used in the step (1) was 1.5 equivalents, the reaction temperature of the step (1) was

-20°C, and the reaction time was 2.4 seconds.

The contents of the collected compounds in the reaction product solution were determined by a gas chromatograph internal standard method. The results are shown below.

Cyclohexanone	55%
Cyclohexyl trifluoroacetate	24%
Cyclohexyl methylthiomethyl ether	4%
Cyclohexanol	15%

Example 8

In the production of cyclohexanone from cyclohexanol by the method of the present invention, the steps (1), (2) and (3) were carried out using the reactors shown below.

Step (1)

A microreactor (manufactured by IMM GmbH, Single Mixer Ver. 2, Inlay: Ag plating, fine liquid introducing channel width: 40 μ m) was used.

To each of two introduction channels for a sulfoxide-containing liquid and an activating agent-containing liquid for the sulfoxide compound, a SUS tube (inner diameter: 1.0 mm, length: 20 cm) was connected, and each channel was connected to a liquid supply source through the SUS tube.

Step (2)

A microreactor (the same as the microreactor for step (1)) was used. A reaction product liquid-discharging channel of the microreactor of the step (1) was connected to a reaction product solution-introducing channel of the microreactor of the step (2) through a connecting SUS tube (inner diameter: 1.0 mm, length: 10 cm), and then an alcohol supply source was connected to an alcohol-introducing channel of a microreactor for the step (2) through a SUS tube (inner diameter: 1.0 mm, length: 20 cm).

Step (3)

A T-joint-type reactor (cross-sectional inner

diameter: 0.8 mm) was used. A reaction product solution-discharging channel of a microreactor of the step (2) was connected to a reaction product solution-introducing channel for the step (3) through a connecting SUS tube (inner diameter: 1.0 mm, length: 10 cm). Also, a basic compound-introducing channel of a microreactor for the step (3) was connected to a basic compound supply source through a SUS tube (inner diameter: 1.0 mm, length: 20 cm) and then a reaction product solution-discharging SUS tube (inner diameter: 1.0 mm, length: 20 cm) was connected to a reaction product solution-discharging channel.

The microreactors for the steps (1), (2) and (3) and the SUS tubes connected thereto were dipped in a constant low-temperature bath set at a constant temperature of -20°C . To the end of the SUS tube for discharging a reaction product solution of the microreactor for the step (3), a SUS tube (inner diameter: 1.0 mm, length: 100 cm) was connected through a connecting tube (inner diameter: 1 mm, length: 50 cm) made of PTFE (polytetrafluoroethylene), and then only the connecting tube was dipped in a water bath at a temperature of 30°C .

By using a gas-tight syringe, a dimethyl sulfoxide/methylene chloride solution having a concentration of 4.0 mol/liter and a trifluoroacetic anhydride (TFAA)/methylene chloride solution having a concentration of 3.0 mol/liter were respectively fed into the microreactor for step (1) at a flow rate of 1.0 ml/min. Immediately after the reaction mixture solution was retained for 2.4 seconds, the reaction product solution was fed into the microreactor for the step (2) and, at the same time, a cyclohexanol/methylene chloride solution having a concentration of 1.0 mol/liter was fed into the microreactor for the step (2) at a flow rate of 2.0 ml/min. Immediately after the reaction mixture solution was retained for 1.2 seconds, the reaction product solution was fed into the microreactor for the

step (3) and, at the same time, a triethylamine/methylene chloride solution having a concentration of 1.4 mol/liter was fed at a flow rate of 4.0 ml/min. After the above reaction operation was carried out for 4 minutes, the resultant reaction product solution discharged from the microreactor for the step (3) was collected in a sample bottle, containing an internal standard substance, for one minute.

The amount of TFAA used in the step (1) was 1.5 equivalents, the reaction temperature of the step (1) was -20°C, and the reaction time was 2.4 seconds.

The contents of the collected compounds in the reaction product solution were determined by a gas chromatograph internal standard method. The results are shown below.

Cyclohexanone	69%
Cyclohexyl trifluoroacetate	7%
Cyclohexyl methylthiomethyl ether	5%
Cyclohexanol	19%

Example 9

In the production of cyclohexanone from cyclohexanol by the method of the present invention, the steps (1), (2) and (3) were carried out using the following reactors.

Step (1)

A microreactor (manufactured by IMM GmbH, Single Mixer Ver. 2, Inlay: Ag plating, fine liquid introducing channel width: 40 µm) was used.

To each of two introduction channels for a sulfoxide-containing liquid and an activating agent-containing liquid for the sulfoxide compound, a SUS tube (inner diameter: 1.0 mm, length: 20 cm) was connected, and each channel was connected to a liquid supply source through the SUS tube.

Step (2)

A T-joint-type reactor (cross-sectional inner diameter: 0.8 mm) was used. A reaction product liquid-

discharging channel of the microreactor of the step (1) was connected to a reaction product solution-introducing channel of the microreactor of the step (2) through a connecting SUS tube (inner diameter: 1.0 mm, length: 10 cm), and then an alcohol supply source was connected to an alcohol-introducing channel of a microreactor for the step (2) through a SUS tube (inner diameter: 1.0 mm, length: 20 cm).

Step (3)

A microreactor (the same as the microreactor for step (1)) was used.

A reaction product solution-discharging channel of a microreactor of the step (2) was connected to a reaction product solution-introducing channel for the step (3) through a connecting SUS tube (inner diameter: 1.0 mm, length: 10 cm). Also, a basic compound-introducing channel of a microreactor for the step (3) was connected to a basic compound supply source through a SUS tube (inner diameter: 1.0 mm, length: 20 cm) and then a reaction product solution-discharging SUS tube (inner diameter: 1.0 mm, length: 20 cm) was connected to a reaction product solution-discharging channel.

The microreactors for the steps (1), (2) and (3) and the SUS tubes connected thereto were dipped in a constant low-temperature bath set at a constant temperature of -20°C . To the end of the SUS tube for discharging a reaction product solution of the microreactor for the step (3), a SUS tube (inner diameter: 1.0 mm, length: 100 cm) was connected through a connecting tube (inner diameter: 1 mm, length: 50 cm) made of PTFE (polytetrafluoroethylene), and then only the connecting tube was dipped in a water bath at a temperature of 30°C .

By using a gas-tight syringe, a dimethyl sulfoxide/methylene chloride solution having a concentration of 4.0 mol/liter and a trifluoroacetic anhydride (TFAA)/methylene chloride solution having a concentration of 2.4 mol/liter were respectively fed into

the microreactor for the step (1) at a flow rate of 1.0 ml/min. Immediately after the reaction mixture solution was retained for 2.4 seconds, the reaction product solution was fed into the microreactor for the step (2) and, at the same time, a cyclohexanol/methylene chloride solution having a concentration of 1.0 mol/liter was fed into the microreactor for the step (2) at a flow rate of 2.0 ml/min. Immediately after the reaction mixture solution was retained for 1.2 seconds, the reaction product solution was fed into the microreactor for the step (3) and, at the same time, a triethylamine/methylene chloride solution having a concentration of 1.4 mol/liter was fed at a flow rate of 4.0 ml/min. After the above reaction operation was carried out for 4 minutes, the reaction product solution was discharged from the microreactor for the step (3) and was collected in a sample bottle, containing an internal standard substance, for one minute.

The amount of TFAA employed in the step (1) was 1.2 equivalents, the reaction temperature of the step (1) was -20°C, and the reaction time was 2.4 seconds.

The contents of the collected compounds in the reaction product solution were determined by a gas chromatograph internal standard method. The results are shown below.

Cyclohexanone	63%
Cyclohexyl trifluoroacetate	22%
Cyclohexyl methylthiomethyl ether	4%
Cyclohexanol	9%

Example 10

In the production of cyclohexanone from cyclohexanol by the method of the present invention, the steps (1), (2) and (3) were carried out using the following reactors.

Step (1)

A microreactor (manufactured by IMM GmbH, Single Mixer Ver. 2, Inlay: Ag plating, fine liquid introducing

channel width: 40 μ m) was used.

To each of two introduction channels for a sulfoxide-containing liquid and an activating agent-containing liquid for the sulfoxide compound, a SUS tube
5 (inner diameter: 1.0 mm, length: 20 cm) was connected, and each channel was connected to a liquid supply source through the SUS tube.

Step (2)

A microreactor (the same as the microreactor for
10 step (1)) was used. A reaction product liquid-discharging channel of the microreactor of the step (1) was connected to a reaction product solution-introducing channel of the microreactor of the step (2) through a
15 connecting SUS tube (inner diameter: 1.0 mm, length: 10 cm), and then an alcohol supply source was connected to an alcohol-introducing channel of a microreactor for the step (2) through a SUS tube (inner diameter: 1.0 mm, length: 20 cm).

Step (3)

20 A microreactor (the same as the microreactor for step (1)) was used.

A reaction product solution-discharging channel of a microreactor of the step (2) was connected to a reaction product solution introducing channel for the step (3)
25 through a connecting SUS tube (inner diameter: 1.0 mm, length: 10 cm). Also, a basic compound-introducing channel of a microreactor for the step (3) was connected to a basic compound supply source through a SUS tube (inner diameter: 1.0 mm, length: 20 cm) and then a
30 reaction product solution-discharging SUS tube (inner diameter: 1.0 mm, length: 20 cm) was connected to a reaction product solution-discharging channel.

The microreactors for the steps (1), (2) and (3) and the SUS tubes connected thereto were dipped in a constant
35 low-temperature bath set at a constant temperature of -20°C . To the end of the SUS tube for discharging a reaction product solution of the microreactor for the

step (3), a SUS tube (inner diameter: 1.0 mm, length: 100 cm) was connected through a connecting tube (inner diameter: 1 mm, length: 50 cm) made of PTFE (polytetrafluoroethylene), and then only the connecting
5 tube was dipped in a water bath at a temperature of 30°C.

By using a gas-tight syringe, a dimethyl sulfoxide/methylene chloride solution having a concentration of 4.0 mol/liter and a trifluoroacetic anhydride (TFAA)/methylene chloride solution having a
10 concentration of 2.0 mol/liter were respectively fed into the microreactor for the step (1) at a flow rate of 1.0 ml/min. Immediately after the reaction mixture solution was retained for 2.4 seconds, the reaction product solution was fed into the microreactor for the step (2)
15 and, at the same time, a cyclohexanol/methylene chloride solution having a concentration of 1.0 mol/liter was fed into the microreactor for the step (2) at a flow rate of 2.0 ml/min. Immediately after the reaction mixture solution was retained for 1.2 seconds, the reaction
20 product solution was fed into the microreactor for step (3) and, at the same time, a triethylamine/methylene chloride solution having a concentration of 1.5 mol/liter was fed at a flow rate of 4.0 ml/min. After the above reaction operation was carried out for 4 minutes, the
25 reaction product solution discharged from the microreactor for the step (3) was collected in a sample bottle, containing an internal standard substance, for one minute.

The amount of TFAA employed in the step (1) was 1.0
30 equivalents, the reaction temperature of the step (1) was -20°C, and the reaction time was 2.4 seconds.

The contents of the collected compounds in the reaction product solution were determined by a gas chromatograph internal standard method. The results are
35 shown below.

Cyclohexanone	67%
Cyclohexyl trifluoroacetate	1%

Cyclohexyl methylthiomethyl ether	4%
Cyclohexanol	23%

Example 11

5 In the production of cyclohexanone from cyclohexanol
by the method of the present invention, the steps (1),
(2) and (3) were carried out using the following
reactors.

Step (1)

10 A microreactor (manufactured by IMM GmbH, Single
Mixer Ver. 2, Inlay: Ag plating, fine liquid introducing
channel width: 40 μ m) was used.

To each of two introduction channels for a
sulfoxide-containing liquid and an activating agent-
containing liquid for the sulfoxide compound, a SUS tube
15 (inner diameter: 1.0 mm, length: 20 cm) was connected,
and each channel was connected to a liquid supply source
through the SUS tube.

Step (2)

20 A microreactor (the same as the microreactor for
step (1)) was used. A reaction product liquid-
discharging channel of the microreactor of step (1) was
connected to a reaction product solution-introducing
channel of the microreactor of step (2) through a
connecting SUS tube (inner diameter: 1.0 mm, length: 10
25 cm), and then an alcohol supply source was connected to
an alcohol introducing channel of a microreactor for the
step (2) through a SUS tube (inner diameter: 1.0 mm,
length: 20 cm).

Step (3)

30 A microreactor (the same as the microreactor for
step (1)) was used.

A reaction product solution-discharging channel of a
microreactor of the step (2) was connected to a reaction
product solution-introducing channel for the step (3)
35 using a connecting SUS tube (inner diameter: 1.0 mm,
length: 10 cm). Also, a basic compound introducing
channel of a microreactor for the step (3) was connected

to a basic compound supply source through a SUS tube
(inner diameter: 1.0 mm, length: 20 cm) and then a
reaction product solution discharging SUS tube (inner
diameter: 1.0 mm, length: 20 cm) was connected to a
5 reaction product solution discharging channel.

The microreactors for the steps (1), (2) and (3) and
the SUS tubes connected thereto were dipped in a constant
low-temperature bath set at a constant temperature of
-20°C. To the end of the SUS tube for discharging a
10 reaction product solution of the microreactor for the
step (3), a SUS tube (inner diameter: 1.0 mm, length: 100
cm) was connected through a connecting tube (inner
diameter: 1 mm, length: 50 cm) made of PTFE
(polytetrafluoroethylene), and then only the connecting
15 tube was dipped in a water bath at a temperature of 30°C.

By using a gas-tight syringe, a dimethyl sulfoxide
(DMSO)/methylene chloride solution having a concentration
of 2.0 mol/liter and a trifluoroacetic anhydride
(TFAA)/methylene chloride solution having a concentration
20 of 2.0 mol/liter were respectively fed into the
microreactor for the step (1) at a flow rate of 1.0
ml/min. Immediately after the reaction mixture solution
was retained for 2.4 seconds, the reaction product
solution was fed into the microreactor for the step (2)
25 and, at the same time, a cyclohexanol/methylene chloride
solution having a concentration of 1.0 mol/liter was fed
into the microreactor for the step (2) at a flow rate of
2.0 ml/min. Immediately after the reaction mixture
solution was retained for 1.2 seconds, the reaction
30 product solution was fed into the microreactor for the
step (3) and, at the same time, a triethylamine/methylene
chloride solution having a concentration of 1.5 mol/liter
was fed at a flow rate of 4.0 ml/min. After the above
reaction operation was carried out for 4 minutes, the
35 reaction product solution was discharged from the
microreactor for the step (3) and was collected in a
sample bottle containing an internal standard substance

for one minute.

The amount of DMSO and TFAA used in the step (1) was 1.0 equivalents, the reaction temperature of the step (1) was -20°C, and the reaction time was 2.4 seconds.

5 The contents of the collected compounds in the reaction product solution were determined by a gas chromatograph internal standard method. The results are shown below.

	Cyclohexanone	69%
10	Cyclohexyl trifluoroacetate	5%
	Cyclohexyl methylthiomethyl ether	4%
	Cyclohexanol	17%

Example 12

15 In the production of cyclohexanone from cyclohexanol by the method of the present invention, the steps (1), (2) and (3) were carried out using the following reactor. Step (1)

20 A microreactor (manufactured by IMM GmbH, Single Mixer Ver. 2, Inlay: Ag plating, fine liquid introducing channel width: 40 µm) was used.

25 To each of two introduction channels for a sulfoxide-containing liquid and an activating agent-containing liquid for the sulfoxide compound, a SUS tube (inner diameter: 1.0 mm, length: 20 cm) was connected, and each channel was connected to a liquid supply source through the SUS tube.

Step (2)

30 A microreactor (the same as the microreactor for step (1)) was used. A reaction product liquid-discharging channel of the microreactor of the step (1) was connected to a reaction product solution-introducing channel of the microreactor of the step (2) through a connecting SUS tube (inner diameter: 1.0 mm, length: 10 cm), and then an alcohol supply source was connected to an alcohol-introducing channel of a microreactor for the step (2) through a SUS tube (inner diameter: 1.0 mm, length: 20 cm).

Step (3)

A microreactor (the same as the microreactor for step (1)) was used.

5 A reaction product solution-discharging channel of a microreactor of the step (2) was connected to a reaction product solution-introducing channel for the step (3) through a connecting SUS tube (inner diameter: 1.0 mm, length: 10 cm). Also, a basic compound-introducing channel of a microreactor for the step (3) was connected
10 to a basic compound supply source through a SUS tube (inner diameter: 1.0 mm, length: 20 cm) and then a reaction product solution-discharging SUS tube (inner diameter: 1.0 mm, length: 20 cm) was connected to a reaction product solution-discharging channel.

15 The microreactors for the steps (1), (2) and (3) and the SUS tubes connected thereto were dipped in a constant low-temperature bath set at a constant temperature of -20°C . To the end of the SUS tube for discharging a reaction product solution of the microreactor for the
20 step (3), a SUS tube (inner diameter: 1.0 mm, length: 100 cm) was connected through a connecting tube (inner diameter: 1 mm, length: 50 cm) made of PTFE (polytetrafluoroethylene), and then only the connecting tube was dipped in a water bath at a temperature of 30°C .

25 By using a gas-tight syringe, a dimethyl sulfoxide/methylene chloride solution having a concentration of 4.0 mol/liter and a trifluoroacetic anhydride (TFAA)/methylene chloride solution having a concentration of 2.4 mol/liter were respectively fed into
30 the microreactor for the step (1) at a flow rate of 1.0 ml/min. Immediately after the reaction mixture solution was retained for 2.4 seconds, the reaction product solution was fed into the microreactor for the step (2) and, at the same time, a cyclohexanol/methylene chloride
35 solution having a concentration of 1.0 mol/liter was fed into the microreactor for the step (2) at a flow rate of 2.0 ml/min. Immediately after the reaction mixture

solution was retained for 1.2 seconds, the reaction product solution was fed into the microreactor for the step (3) and, at the same time, a triethylamine/methylene chloride solution having a concentration of 3.0 mol/liter was fed at a flow rate of 4.0 ml/min. After the above reaction operation was carried out for 4 minutes, the reaction product solution was discharged from the microreactor for the step (3) and was collected in a sample bottle, containing an internal standard substance, for one minute.

The amount of TFAA employed in the step (1) was 1.2 equivalents, the reaction temperature of the step (1) was -20°C, and the reaction time was 2.4 seconds.

The contents of the collected compounds in the reaction product solution were determined by a gas chromatograph internal standard method. The results are shown below.

	Cyclohexanone	74%
	Cyclohexyl trifluoroacetate	2%
20	Cyclohexyl methylthiomethyl ether	4%
	Cyclohexanol	15%

Example 13

In the production of cyclohexanone from cyclohexanol by the method of the present invention, the steps (1), (2) and (3) were carried out using the following reactor. Step (1)

A microreactor (manufactured by IMM GmbH, Single Mixer Ver. 2, Inlay: Ag plating, fine liquid introducing channel width: 40 µm) was used.

To each of two introduction channels for a sulfoxide-containing liquid-introducing channel and an activating agent-containing liquid for the sulfoxide compound, a SUS tube (inner diameter: 1.0 mm, length: 20 cm) was connected, and each channel was connected to a liquid supply source through the SUS tube.

Step (2)

A microreactor (the same as the microreactor for

step (1)) was used. A reaction product liquid-discharging channel of the microreactor of the step (1) was connected to a reaction product solution-introducing channel of the microreactor of the step (2) through a
5 connecting SUS tube (inner diameter: 1.0 mm, length: 10 cm), and then an alcohol supply source was connected to an alcohol-introducing channel of a microreactor for the step (2) through a SUS tube (inner diameter: 1.0 mm, length: 20 cm).

10 Step (3)

A microreactor (the same as microreactor for the step (1)) was used.

A reaction product solution-discharging channel of a microreactor of step (2) was connected to a reaction
15 product solution-introducing channel for step (3) through a connecting SUS tube (inner diameter: 1.0 mm, length: 10 cm). Also, a basic compound introducing channel of a microreactor for step (3) was connected to a basic compound supply source through a SUS tube (inner
20 diameter: 1.0 mm, length: 20 cm) and then a reaction product solution-discharging SUS tube (inner diameter: 1.0 mm, length: 20 cm) was connected to a reaction product solution discharging channel.

The microreactors for steps (1), (2) and (3) and the
25 SUS tubes connected thereto were dipped in a constant low-temperature bath set at a constant temperature of -20°C . To the end of the SUS tube for discharging a reaction product solution of the microreactor for the step (3), a SUS tube (inner diameter: 1.0 mm, length: 100
30 cm) was connected through a connecting tube (inner diameter: 1 mm, length: 50 cm) made of PTFE (polytetrafluoroethylene), and then only the connecting tube was dipped in a water bath at a temperature of 30°C .

By using a gas-tight syringe, a dimethyl
35 sulfoxide/methylene chloride solution having a concentration of 0.8 mol/liter and a trifluoroacetic anhydride (TFAA)/methylene chloride solution having a

concentration of 0.5 mol/liter were respectively fed into the microreactor for the step (1) at a flow rate of 1.0 ml/min. Immediately after the reaction mixture solution was retained for 2.4 seconds, the reaction product solution was fed into the microreactor for the step (2) and, at the same time, a cyclohexanol/methylene chloride solution having a concentration of 0.2 mol/liter was fed into the microreactor for the step (2) at a flow rate of 2.0 ml/min. Immediately after the reaction mixture solution was retained for 1.2 seconds, the reaction product solution was fed into the microreactor for the step (3) and, at the same time, a triethylamine/methylene chloride solution having a concentration of 0.3 mol/liter was fed at a flow rate of 4.0 ml/min. After the above reaction operation was carried out for 4 minutes, the reaction product solution was discharged from the microreactor for step (3) and was collected in a sample bottle, containing an internal standard substance, for one minute.

The amount of TFAA employed in step (1) was 1.2 equivalents, the reaction temperature of the step (1) was -20°C, and the reaction time was 2.4 seconds.

The contents of the collected compounds in the reaction product solution was determined by a gas chromatograph internal standard method. The results are shown below.

Cyclohexanone	84%
Cyclohexyl trifluoroacetate	4%
Cyclohexyl methylthiomethyl ether	5%
Cyclohexanol	9%

Example 14

In the production of cyclohexanone from cyclohexanol by the method of the present invention, the steps (1), (2) and (3) were carried out using the following reactor.

Step (1)

A microreactor (manufactured by IMM GmbH, Single Mixer Ver. 2, Inlay: Ag plating, fine liquid introducing

channel width: 40 μ m) was used.

To each of two introduction channels for a sulfoxide-containing liquid and an activating agent-containing liquid for the sulfoxide compound, a SUS tube
5 (inner diameter: 1.0 mm, length: 20 cm) was connected, and each channel was connected to a liquid supply source through the SUS tube.

Step (2)

A microreactor (the same as the microreactor for
10 step (1)) was used. A reaction product liquid-discharging channel of the microreactor of the step (1) was connected to a reaction product solution-introducing channel of the microreactor of the step (2) through a
15 connecting SUS tube (inner diameter: 1.0 mm, length: 10 cm), and then an alcohol supply source was connected to an alcohol introducing channel of a microreactor for the step (2) through a SUS tube (inner diameter: 1.0 mm, length: 20 cm).

Step (3)

20 A microreactor (the same as the microreactor for step (1)) was used.

A reaction product solution-discharging channel of a microreactor of the step (2) was connected to a reaction product solution-introducing channel for the step (3)
25 through a connecting SUS tube (inner diameter: 1.0 mm, length: 10 cm). Also, a basic compound-introducing channel of a microreactor for the step (3) was connected to a basic compound supply source through a SUS tube (inner diameter: 1.0 mm, length: 20 cm) and then a
30 reaction product solution-discharging SUS tube (inner diameter: 1.0 mm, length: 20 cm) was connected to a reaction product solution discharging channel.

The microreactors for the steps (1), (2) and (3) and the SUS tubes connected thereto were dipped in a constant
35 low-temperature bath set at a constant temperature of 0°C. To the end of the SUS tube for discharging a reaction product solution of the microreactor for the step (3), a

SUS tube (inner diameter: 1.0 mm, length: 100 cm) was connected through a connecting tube (inner diameter: 1 mm, length: 50 cm) made of PTFE (polytetrafluoroethylene), and then only the connecting tube was dipped in a water bath at a temperature of 30°C.

By using a gas-tight syringe, a dimethyl sulfoxide/methylene chloride solution having a concentration of 4.0 mol/liter and a trifluoroacetic anhydride (TFAA)/methylene chloride solution having a concentration of 3.0 mol/liter were respectively fed into the microreactor for the step (1) at a flow rate of 1.0 ml/min. Immediately after the reaction mixture solution was retained for 2.4 seconds, the reaction product solution was fed into the microreactor for the step (2) and, at the same time, a cyclohexanol/methylene chloride solution having a concentration of 1.0 mol/liter was fed into the microreactor for the step (2) at a flow rate of 2.0 ml/min. Immediately after the reaction mixture solution was retained for 1.2 seconds, the reaction product solution was fed into the microreactor for the step (3) and, at the same time, a triethylamine/methylene chloride solution having a concentration of 1.4 mol/liter was fed at a flow rate of 4.0 ml/min. After the above reaction operation was carried out for 4 minutes, the reaction product solution was discharged from the microreactor for step (3) and was collected in a sample bottle, containing an internal standard substance, for one minute.

The amount of TFAA employed in the step (1) was 1.5 equivalents, the reaction temperature of the step (1) was 0°C, and the reaction time was 2.4 seconds.

The contents of the collected compounds in the reaction product solution were determined by a gas chromatograph internal standard method. The results are shown below.

Cyclohexanone	36%
Cyclohexyl trifluoroacetate	9%

Cyclohexyl methylthiomethyl ether	2%
Cyclohexanol	48%

Example 15

5 In the production of decanal from decanol by the method of the present invention, the steps (1), (2) and (3) were carried out using the following reactor.

Step (1)

10 A microreactor (manufactured by IMM GmbH, Single Mixer Ver. 2, Inlay: Ag plating, fine liquid introducing channel width: 40 μ m) was used.

To each of two introduction channels for a sulfoxide-containing liquid and an activating agent-containing liquid for the sulfoxide compound, a SUS tube (inner diameter: 1.0 mm, length: 20 cm) was connected, 15 and the each channel was connected to a liquid supply source through the SUS tube.

Step (2)

A microreactor (the same as the microreactor for step (1)) was used. A reaction product liquid 20 discharging channel of the microreactor of the step (1) was connected to a reaction product solution introducing channel of the microreactor of the step (2) through a connecting SUS tube (inner diameter: 1.0 mm, length: 10 cm), and then an alcohol supply source was connected to 25 an alcohol introducing channel of a microreactor for the step (2) through a SUS tube (inner diameter: 1.0 mm, length: 20 cm).

Step (3)

30 A microreactor (the same as the microreactor for step (1)) was used.

A reaction product solution discharging-channel of a microreactor of the step (2) was connected to a reaction product solution-introducing channel for the step (3) through a connecting SUS tube (inner diameter: 1.0 mm, 35 length: 10 cm). Also, a basic compound-introducing channel of a microreactor for the step (3) was connected to a basic compound supply source through a SUS tube

(inner diameter: 1.0 mm, length: 20 cm) and then a reaction product solution-discharging SUS tube (inner diameter: 1.0 mm, length: 20 cm) was connected to a reaction product solution-discharging channel.

5 The microreactors for steps (1), (2) and (3) and the SUS tubes connected thereto were dipped in a constant low-temperature bath set at a constant temperature of -20°C. To the end of the SUS tube for discharging a reaction product solution of the microreactor for the
10 step (3), a SUS tube (inner diameter: 1.0 mm, length: 100 cm) was connected through a connecting tube (inner diameter: 1 mm, length: 50 cm) made of PTFE (polytetrafluoroethylene), and then only the connecting tube was dipped in a water bath at a temperature of 30°C.

15 By using a gas-tight syringe, a dimethyl sulfoxide/methylene chloride solution having a concentration of 4.0 mol/liter and a trifluoroacetic anhydride (TFAA)/methylene chloride solution having a concentration of 2.4 mol/liter were respectively fed into
20 the microreactor for step (1) at a flow rate of 1.0 ml/min. Immediately after the reaction mixture solution was retained for 2.4 seconds, the reaction product solution was fed into the microreactor for the step (2) and, at the same time, a decanol/methylene chloride
25 solution having a concentration of 1.0 mol/liter was fed into the microreactor for the step (2) at a flow rate of 2.0 ml/min. Immediately after the reaction mixture solution was retained for 1.2 seconds, the reaction product solution was fed into the microreactor for the
30 step (3) and, at the same time, a triethylamine/methylene chloride solution having a concentration of 1.5 mol/liter was fed at a flow rate of 4.0 ml/min. After the above reaction operation was carried out for 4 minutes, the reaction product solution was discharged from the
35 microreactor for the step (3) and was collected in a sample bottle, containing an internal standard substance, for one minute.

The amount of TFAA employed in the step (1) was 1.2 equivalents, the reaction temperature of the step (1) was -20°C, and the reaction time was 2.4 seconds.

5 The contents of the collected compounds in the reaction product solution were determined by a gas chromatograph internal standard method. The results are shown below.

	Decanal	71%
	Decyl trifluoroacetate	18%
10	Decyl methylthiomethyl ether	8%
	Decanol	5%

Example 16

In the production of 2-octanone from 2-octanol by the method of the present invention, the steps (1), (2)
15 and (3) were carried out using the following reactors.
Step (1)

A microreactor (manufactured by IMM GmbH, Single Mixer Ver. 2, Inlay: Ag plating, fine liquid introducing channel width: 40 µm) was used.

20 To each of two introduction channels for a sulfoxide-containing liquid and an activating agent-containing liquid for the sulfoxide compound, a SUS tube (inner diameter: 1.0 mm, length: 20 cm) was connected, and each channel was connected to a liquid supply source,
25 through the SUS tube.

Step (2)

A microreactor (the same as the microreactor for step (1)) was used. A reaction product liquid-discharging channel of the microreactor of step (1) was
30 connected to a reaction product solution-introducing channel of the microreactor of the step (2) through a connecting SUS tube (inner diameter: 1.0 mm, length: 10 cm), and then an alcohol supply source was connected to an alcohol-introducing channel of a microreactor for step
35 (2) through a SUS tube (inner diameter: 1.0 mm, length: 20 cm).

Step (3)

A microreactor (the same as the microreactor for step (1)) was used.

5 A reaction product solution-discharging channel of a microreactor of the step (2) was connected to a reaction product solution-introducing channel for the step (3) through a connecting SUS tube (inner diameter: 1.0 mm, length: 10 cm). Also, a basic compound-introducing channel of a microreactor for the step (3) was connected to a basic compound supply source through a SUS tube
10 (inner diameter: 1.0 mm, length: 20 cm) and then a reaction product solution discharging SUS tube (inner diameter: 1.0 mm, length: 20 cm) was connected to a reaction product solution-discharging channel.

15 The microreactors for the steps (1), (2) and (3) and the SUS tubes connected thereto were dipped in a constant low-temperature bath set at a constant temperature of -20°C . To the end of the SUS tube for discharging a reaction product solution of the microreactor for the step (3), a SUS tube (inner diameter: 1.0 mm, length: 100
20 cm) was connected using a connecting tube (inner diameter: 1 mm, length: 50 cm) made of PTFE (polytetrafluoroethylene), and then only the connecting tube was dipped in a water bath at a temperature of 30°C .

25 By using a gas-tight syringe, a dimethyl sulfoxide/methylene chloride solution having a concentration of 4.0 mol/liter and a trifluoroacetic anhydride (TFAA)/methylene chloride solution having a concentration of 2.4 mol/liter were respectively fed into the microreactor for the step (1) at a flow rate of 1.0
30 ml/min. Immediately after the reaction mixture solution was retained for 2.4 seconds, the reaction product solution was fed into the microreactor for the step (2) and, at the same time, a 2-octanol/methylene chloride solution having a concentration of 1.0 mol/liter was fed
35 into the microreactor for the step (2) at a flow rate of 2.0 ml/min. Immediately after the reaction mixture solution was retained for 1.2 seconds, the reaction

product solution was fed into the microreactor for the step (3) and, at the same time, a triethylamine/methylene chloride solution having a concentration of 1.5 mol/liter was fed at a flow rate of 4.0 ml/min. After the above reaction operation was carried out for 4 minutes, the reaction product solution was discharged from the microreactor for the step (3) and was collected in a sample bottle, containing an internal standard substance, for one minute.

The amount of TFAA employed in step (1) was 1.2 equivalents, the reaction temperature of step (1) was -20°C, and the reaction time was 2.4 seconds.

The contents of the collected compounds in the reaction product solution were determined by a gas chromatograph internal standard method. The results are shown below.

2-octanone	87%
Octyl trifluoroacetate	2%
Octyl methylthiomethyl ether	5%
2-octanol	8%

Example 17

In the production of cyclohexanone from cyclohexanol by the method of the present invention, the steps (1), (2) and (3) were carried out using the following reactors.

Step (1)

A microreactor (manufactured by IMM GmbH, Single Mixer Ver. 2, Inlay: Ag plating, fine liquid introducing channel width: 40 µm) was used.

To each of two introduction channels for a sulfoxide-containing liquid and an activating agent-containing liquid for the sulfoxide compound, a SUS tube (inner diameter: 1.0 mm, length: 20 cm) was connected, and each channel was connected to a liquid supply source through the SUS tube.

Step (2)

A microreactor (the same as the microreactor for

step (1)) was used. A reaction product liquid-discharging channel of the microreactor of the step (1) was connected to a reaction product solution-introducing channel of the microreactor of the step (2) through a
5 connecting SUS tube (inner diameter: 1.0 mm, length: 10 cm), and then an alcohol supply source was connected to an alcohol-introducing channel of a microreactor for the step (2) through a SUS tube (inner diameter: 1.0 mm, length: 20 cm).

10 Step (3)

A microreactor (the same as the microreactor for step (1)) was used.

A reaction product solution-discharging channel of a microreactor of step (2) was connected to a reaction
15 product solution-introducing channel for the step (3) through a connecting SUS tube (inner diameter: 1.0 mm, length: 10 cm). Also, a basic compound-introducing channel of a microreactor for step (3) was connected to a basic compound supply source through a SUS tube (inner
20 diameter: 1.0 mm, length: 20 cm) and then a reaction product solution-discharging SUS tube (inner diameter: 1.0 mm, length: 20 cm) was connected to a reaction product solution-discharging channel.

The microreactors for the steps (1), (2) and (3) and
25 the SUS tubes connected thereto were dipped in a constant low-temperature bath set at a constant temperature of -20°C . To the end of the SUS tube for discharging a reaction product solution of the microreactor for the step (3), a SUS tube (inner diameter: 1.0 mm, length: 100
30 cm) was connected through a connecting tube (inner diameter: 1 mm, length: 50 cm) made of PTFE (polytetrafluoroethylene), and then only the connecting tube was dipped in a water bath at a temperature of 30°C .

By using a gas-tight syringe, a dimethyl
35 sulfoxide/methylene chloride solution having a concentration of 4.0 mol/liter and a trifluoroacetic anhydride (TFAA)/methylene chloride solution having a

concentration of 2.4 mol/liter were respectively fed into the microreactor for the step (1) at a flow rate of 1.0 ml/min. Immediately after the reaction mixture solution was retained for 2.4 seconds, the reaction product solution was fed into the microreactor for step (2) and, at the same time, a cyclohexanol/methylene chloride solution having a concentration of 1.0 mol/liter was fed into the microreactor for step (2) at a flow rate of 2.0 ml/min. Immediately after the reaction mixture solution was retained for 1.2 seconds, the reaction product solution was fed into the microreactor for step (3) and, at the same time, a triethylamine/methylene chloride solution having a concentration of 1.4 mol/liter was fed at a flow rate of 4.0 ml/min. After the above reaction operation was carried out for 4 minutes, the reaction product solution was discharged from the microreactor for the step (3) and was collected in a sample bottle containing an internal standard substance for one minute.

The amount of TFAA employed in the step (1) was 1.2 equivalents, the reaction temperature of the step (1) was -20°C, and the reaction time was 2.4 seconds.

The contents of the collected compounds in the reaction product solution were determined by a gas chromatograph internal standard method. The results are shown below.

Cyclohexanone	77%
Cyclohexyl trifluoroacetate	4%
Cyclohexyl methylthiomethyl ether	5%
Cyclohexanol	12%

Example 18

In the production of benzaldehyde from benzyl alcohol by the method of the present invention, the steps (1), (2) and (3) were carried out using the following reactor.

Step (1)

A microreactor (manufactured by IMM GmbH, Single Mixer Ver. 2, Inlay: Ag plating, fine liquid introducing

channel width: 40 μ m) was used.

To each of two introduction channels for a sulfoxide-containing liquid and an activating agent-containing liquid for the sulfoxide compound, a SUS tube
5 (inner diameter: 1.0 mm, length: 20 cm) was connected, and each channel was connected to a liquid supply source through the SUS tube.

Step (2)

A microreactor (the same as the microreactor for
10 step (1)) was used. A reaction product liquid-discharging channel of the microreactor of the step (1) was connected to a reaction product solution-introducing channel of the microreactor of the step (2) through a
15 connecting SUS tube (inner diameter: 1.0 mm, length: 10 cm), and then an alcohol supply source was connected to an alcohol-introducing channel of a microreactor for the step (2) through a SUS tube (inner diameter: 1.0 mm, length: 20 cm).

Step (3)

20 A microreactor (the same as the microreactor for step (1)) was used.

A reaction product solution-discharging channel of a microreactor of the step (2) was connected to a reaction product solution-introducing channel for the step (3)
25 through a connecting SUS tube (inner diameter: 1.0 mm, length: 10 cm). Also, a basic compound-introducing channel of a microreactor for the step (3) was connected to a basic compound supply source through a SUS tube (inner diameter: 1.0 mm, length: 20 cm) and then a
30 reaction product solution-discharging SUS tube (inner diameter: 1.0 mm, length: 20 cm) was connected to a reaction product solution-discharging channel.

The microreactors for the steps (1), (2) and (3) and the SUS tubes connected thereto were dipped in a constant
35 low-temperature bath set at a constant temperature of -20°C . To the end of the SUS tube for discharging a reaction product solution of the microreactor for the

step (3), a SUS tube (inner diameter: 1.0 mm, length: 100 cm) was connected through a connecting tube (inner diameter: 1 mm, length: 50 cm) made of PTFE (polytetrafluoroethylene), and then only the connecting
5 tube was dipped in a water bath at a temperature of 30°C.

By using a gas-tight syringe, a dimethyl sulfoxide/methylene chloride solution having a concentration of 4.0 mol/liter and a trifluoroacetic anhydride (TFAA)/methylene chloride solution having a
10 concentration of 2.4 mol/liter were respectively fed into the microreactor for the step (1) at a flow rate of 1.0 ml/min. Immediately after the reaction mixture solution was retained for 2.4 seconds, the reaction product solution was fed into the microreactor for the step (2)
15 and, at the same time, a benzyl alcohol/methylene chloride solution having a concentration of 1.0 mol/liter was fed into the microreactor for the step (2) at a flow rate of 2.0 ml/min. Immediately after the reaction mixture solution was retained for 1.2 seconds, the
20 reaction product solution was fed into the microreactor for the step (3) and, at the same time, a triethylamine/methylene chloride solution having a concentration of 1.5 mol/liter was fed at a flow rate of 4.0 ml/min. After the above reaction operation was
25 carried out for 4 minutes, the reaction product solution was discharged from the microreactor for the step (3) and was collected in a sample bottle, containing an internal standard substance, for one minute.

The amount of TFAA employed in the step (1) was 1.2
30 equivalents, the reaction temperature of the step (1) was -20°C, and the reaction time was 2.4 seconds.

The contents of the collected compounds in the reaction product solution were determined by a gas chromatograph internal standard method. The results are
35 shown below.

Benzaldehyde	88%
Benzyl trifluoroacetate	8%

Benzyl alcohol

3%

Example 19

In the production of cyclohexanone from cyclohexanol by the method of the present invention, the steps (1),
5 (2) and (3) were carried out by using the following reactors.

Step (1)

A microreactor (manufactured by IMM GmbH, Single Mixer Ver. 2, Inlay: Ag plating, fine liquid introducing
10 channel width: 40 μ m) was used.

To each of two introduction channels for a sulfoxide-containing liquid and an activating agent-containing liquid for the sulfoxide compound, a SUS tube (inner diameter: 1.0 mm, length: 20 cm) was connected,
15 each channel was connected to a liquid supply source through the SUS tube.

Step (2)

A microreactor (the same as the microreactor for step (1)) was used. A reaction product liquid-discharging channel of the microreactor of the step (1)
20 was connected to a reaction product solution-introducing channel of the microreactor of the step (2) through a connecting SUS tube (inner diameter: 0.1 mm, length: 3.2 cm), and then an alcohol supply source was connected to
25 an alcohol-introducing channel of the microreactor for the step (2) through a SUS tube (inner diameter: 1.0 mm, length: 20 cm).

Step (3)

A microreactor (the same as the microreactor for
30 step (1)) was used.

A reaction product solution-discharging channel of a microreactor of the step (2) was connected to a reaction product solution-introducing channel for the step (3) through a connecting SUS tube (inner diameter: 1.0 mm,
35 length: 10 cm). Also, a basic compound-introducing channel of a microreactor for step (3) was connected to a basic compound supply source through a SUS tube (inner

diameter: 1.0 mm, length: 20 cm) and then a reaction product solution-discharging SUS tube (inner diameter: 1.0 mm, length: 20 cm) was connected to a reaction product solution-discharging channel.

5 The microreactors for the steps (1), (2) and (3) and the SUS tubes connected thereto were dipped in a constant low-temperature bath set at a constant temperature of -20°C. To the end of the SUS tube for discharging a reaction product solution of the microreactor for the
10 step (3), a SUS tube (inner diameter: 1.0 mm, length: 100 cm) was connected through a connecting tube (inner diameter: 1 mm, length: 50 cm) made of PTFE (polytetrafluoroethylene), and then only the connecting tube was dipped in a water bath at a temperature of 30°C.

15 By using a gas-tight syringe, a dimethyl sulfoxide/methylene chloride solution having a concentration of 4.0 mol/liter and a trifluoroacetic anhydride (TFAA)/methylene chloride solution having a concentration of 2.4 mol/liter were respectively fed into
20 the microreactor for step (1) at a flow rate of 1.0 ml/min. Immediately after the reaction mixture solution was retained for 0.01 seconds, the reaction product solution was fed into the microreactor for step (2) and, at the same time, a cyclohexanol/methylene chloride
25 solution having a concentration of 1.0 mol/liter was fed into the microreactor for the step (2) at a flow rate of 2.0 ml/min. Immediately after the reaction mixture solution was retained for 1.2 seconds, the reaction product solution was fed into the microreactor for the
30 step (3) and, at the same time, a triethylamine/methylene chloride solution having a concentration of 1.5 mol/liter was fed at a flow rate of 4.0 ml/min. After the above reaction operation was carried out for 4 minutes, the reaction product solution was discharged from the
35 microreactor for step (3) and was collected in a sample bottle, containing an internal standard substance, for one minute.

The amount of TFAA employed in the step (1) was 1.2 equivalents, the reaction temperature of the step (1) was -20°C, and the reaction time was 0.01 seconds.

5 The contents of the collected compounds in the reaction product solution were determined by a gas chromatograph internal standard method. The results are shown below.

	Cyclohexanone	75%
	Cyclohexyl trifluoroacetate	1%
10	Cyclohexyl methylthiomethyl ether	6%
	Cyclohexanol	15%

Example 20

In the production of cyclohexanone from cyclohexanol by the method of the present invention, the steps (1),
15 (2) and (3) were carried out by using the following reactor.

Step (1)

A microreactor (manufactured by IMM GmbH, Single Mixer Ver. 2, Inlay: Ag plating, fine liquid introducing
20 channel width: 40 µm) was used.

To each of two introduction channels for a sulfoxide-containing liquid and an activating agent-containing liquid for the sulfoxide compound, a SUS tube (inner diameter: 1.0 mm, length: 20 cm) was connected,
25 and each channel was connected to a liquid supply source through the SUS tube.

Step (2)

A microreactor (the same as the microreactor for step (1)) was used. A reaction product liquid-
30 discharging channel of the microreactor of step (1) was connected to a reaction product solution-introducing channel of the microreactor of step (2) using a connecting SUS tube (inner diameter: 0.1 mm, length: 3.2 cm), and then an alcohol supply source was connected to
35 an alcohol-introducing channel of a microreactor for the step (2) through a SUS tube (inner diameter: 1.0 mm, length: 20 cm).

Step (3)

A microreactor (the same as the microreactor for step (1)) was used.

5 A reaction product solution-discharging channel of a microreactor of the step (2) was connected to a reaction product solution-introducing channel for the step (3) through a connecting SUS tube (inner diameter: 1.0 mm, length: 10 cm). Also, a basic compound-introducing channel of a microreactor for the step (3) was connected
10 to a basic compound supply source through a SUS tube (inner diameter: 1.0 mm, length: 20 cm) and then a reaction product solution-discharging SUS tube (inner diameter: 1.0 mm, length: 20 cm) was connected to a reaction product solution-discharging channel.

15 The microreactors for the steps (1), (2) and (3) and the SUS tubes connected thereto were dipped in a constant low-temperature bath set at a constant temperature of 0°C. To the end of the SUS tube for discharging a reaction product solution of the microreactor for the step (3), a
20 SUS tube (inner diameter: 1.0 mm, length: 100 cm) was connected through a connecting tube (inner diameter: 1 mm, length: 50 cm) made of PTFE (polytetrafluoroethylene), and then only the connecting tube was dipped in a water bath at a temperature of 30°C.

25 By using a gas-tight syringe, a dimethyl sulfoxide/methylene chloride solution having a concentration of 4.0 mol/liter and a trifluoroacetic anhydride (TFAA)/methylene chloride solution having a concentration of 2.4 mol/liter were respectively fed into
30 the microreactor for the step (1) at a flow rate of 1.0 ml/min. Immediately after the reaction mixture solution was retained for 0.01 seconds, the reaction product solution was fed into the microreactor for the step (2) and, at the same time, a cyclohexanol/methylene chloride
35 solution having a concentration of 1.0 mol/liter was fed into the microreactor for the step (2) at a flow rate of 2.0 ml/min. Immediately after the reaction mixture

solution was retained for 1.2 seconds, the reaction product solution was fed into the microreactor for the step (3) and, at the same time, a triethylamine/methylene chloride solution having a concentration of 1.5 mol/liter was fed at a flow rate of 4.0 ml/min. After the above reaction operation was carried out for 4 minutes, the reaction product solution was discharged from the microreactor for step (3) and was collected in a sample bottle, containing an internal standard substance, for one minute.

The amount of TFAA employed in the step (1) was 1.2 equivalents, the reaction temperature of the step (1) was 0°C, and the reaction time was 0.01 seconds.

The contents of the collected compounds in the reaction product solution were determined by a gas chromatograph internal standard method. The results are shown below.

	Cyclohexanone	80%
	Cyclohexyl trifluoroacetate	1%
20	Cyclohexyl methylthiomethyl ether	6%
	Cyclohexanol	10%

Example 21

In the production of cyclohexanone from cyclohexanol by the method of the present invention, the steps (1), (2) and (3) were carried out by using the following reactor.

Step (1)

A microreactor (manufactured by IMM GmbH, Single Mixer Ver. 2, Inlay: Ag plating, fine liquid introducing channel width: 40 µm) was used.

To each of two introduction channels for a sulfoxide-containing liquid and an activating agent-containing liquid for the sulfoxide compound, a SUS tube (inner diameter: 1.0 mm, length: 20 cm) was connected, and each channel was connected to a liquid supply source through the SUS tube.

Step (2)

A microreactor (the same as the microreactor for step (1)) was used. A reaction product liquid-discharging channel of the microreactor of the step (1) was connected to a reaction product solution-introducing channel of the microreactor of the step (2) through a connecting SUS tube (inner diameter: 0.1 mm, length: 3.2 cm), and then an alcohol supply source was connected to an alcohol-introducing channel of a microreactor for the step (2) through a SUS tube (inner diameter: 1.0 mm, length: 20 cm).

Step (3)

A microreactor (the same as the microreactor for step (1)) was used.

A reaction product solution-discharging channel of a microreactor of step (2) was connected to a reaction product solution-introducing channel for step (3) through a connecting SUS tube (inner diameter: 1.0 mm, length: 10 cm). Also, a basic compound introducing channel of a microreactor for the step (3) was connected to a basic compound supply source through a SUS tube (inner diameter: 1.0 mm, length: 20 cm) and then a reaction product solution-discharging SUS tube (inner diameter: 1.0 mm, length: 20 cm) was connected to a reaction product solution-discharging channel.

The microreactors for the steps (1), (2) and (3) and the SUS tubes connected thereto were dipped in a constant low-temperature bath set at a constant temperature of 20°C. To the end of the SUS tube for discharging a reaction product solution of the microreactor for the step (3), a SUS tube (inner diameter: 1.0 mm, length: 100 cm) was connected through a connecting tube (inner diameter: 1 mm, length: 50 cm) made of PTFE (polytetrafluoroethylene), and then only the connecting tube was dipped in a water bath at a temperature of 30°C.

By using a gas-tight syringe, a dimethyl sulfoxide/methylene chloride solution having a concentration of 4.0 mol/liter and a trifluoroacetic

anhydride (TFAA)/methylene chloride solution having a concentration of 2.4 mol/liter were respectively fed into the microreactor for the step (1) at a flow rate of 1.0 ml/min. Immediately after the reaction mixture solution was retained for 0.01 seconds, the reaction product solution was fed into the microreactor for the step (2) and, at the same time, a cyclohexanol/methylene chloride solution having a concentration of 1.0 mol/liter was fed into the microreactor for the step (2) at a flow rate of 2.0 ml/min. Immediately after the reaction mixture solution was retained for 1.2 seconds, the reaction product solution was fed into the microreactor for step (3) and, at the same time, a triethylamine/methylene chloride solution having a concentration of 1.4 mol/liter was fed at a flow rate of 4.0 ml/min. After the above reaction operation was carried out for 4 minutes, the reaction product solution was discharged from the microreactor for step (3) and was collected in a sample bottle, containing an internal standard substance, for one minute.

The amount of TFAA employed in the step (1) was 1.2 equivalents, the reaction temperature of the step (1) was 20°C, and the reaction time was 0.01 seconds.

The contents of the collected compounds in the reaction product solution were determined by a gas chromatograph internal standard method. The results are shown below.

	Cyclohexanone	71%
	Cyclohexyl trifluoroacetate	2%
30	Cyclohexyl methylthiomethyl ether	4%
	Cyclohexanol	19%

Example 22

In the production of cyclohexanone from cyclohexanol by the method of the present invention, the steps (1), (2) and (3) were carried out using the following reactor. Step (1)

A microreactor (manufactured by IMM GmbH, Single

Mixer Ver. 2, Inlay: Ag plating, fine liquid introducing channel width: 40 μ m) was used.

5 To each of two introduction channels for a sulfoxide-containing liquid and an activating agent-containing liquid for the sulfoxide compound, a SUS tube (inner diameter: 1.0 mm, length: 20 cm) was connected, and each channel was connected to a liquid supply source through the SUS tube.

Step (2)

10 A microreactor (the same as the microreactor for step (1)) was used. A reaction product liquid-discharging channel of the microreactor of the step (1) was connected to a reaction product solution-introducing channel of the microreactor of the step (2) through a
15 connecting SUS tube (inner diameter: 1.0 mm, length: 10 cm), and then an alcohol supply source was connected to an alcohol-introducing channel of a microreactor for the step (2) through a SUS tube (inner diameter: 1.0 mm, length: 20 cm).

20 Step (3)

A microreactor (the same as microreactor for the step (1)) was used.

A reaction product solution-discharging channel of a microreactor of step (2) was connected to a reaction
25 product solution-introducing channel for step (3) through a connecting SUS tube (inner diameter: 1.0 mm, length: 10 cm). Also, a basic compound-introducing channel of a microreactor for step (3) was connected to a basic compound supply source through a SUS tube (inner
30 diameter: 1.0 mm, length: 20 cm) and then a reaction product solution-discharging SUS tube (inner diameter: 1.0 mm, length: 20 cm) was connected to a reaction product solution-discharging channel.

35 The microreactors for the steps (1), (2) and (3) and the SUS tubes connected thereto were dipped in a constant low-temperature bath set at a constant temperature of 0°C. To the end of the SUS tube for discharging a reaction

product solution of the microreactor for the step (3), a SUS tube (inner diameter: 1.0 mm, length: 100 cm) was connected through a connecting tube (inner diameter: 1 mm, length: 50 cm) made of PTFE

5 (polytetrafluoroethylene), and then only the connecting tube was dipped in a water bath at a temperature of 30°C.

By using a gas-tight syringe, a dimethyl sulfoxide/methylene chloride solution having a concentration of 4.0 mol/liter and a trifluoroacetic anhydride (TFAA)/methylene chloride solution having a
10 concentration of 2.4 mol/liter were respectively fed into the microreactor for step (1) at a flow rate of 1.0 ml/min. Immediately after the reaction mixture solution was retained for 2.3 seconds, the reaction product
15 solution was fed into the microreactor for step (2) and, at the same time, a cyclohexanol/methylene chloride solution having a concentration of 1.0 mol/liter was fed into the microreactor for the step (2) at a flow rate of 2.0 ml/min. Immediately after the reaction mixture
20 solution was retained for 1.2 seconds, the reaction product solution was fed into the microreactor for step (3) and, at the same time, a triethylamine/methylene chloride solution having a concentration of 1.5 mol/liter was fed at a flow rate of 4.0 ml/min. After the above
25 reaction operation was carried out for 4 minutes, the reaction product solution was discharged from the microreactor for the step (3) and was collected in a sample bottle, containing an internal standard substance, for one minute.

30 The amount of TFAA employed in the step (1) was 1.2 equivalents, the reaction temperature of the step (1) was 0°C, and the reaction time was 2.4 seconds.

The contents of the collected compounds in the reaction product solution were determined by a gas
35 chromatograph internal standard method. The results are shown below.

Cyclohexanone

32%

Cyclohexyl trifluoroacetate	7%
Cyclohexyl methylthiomethyl ether	3%
Cyclohexanol	50%

Example 23

5 In the production of cyclohexanone from cyclohexanol by the method of the present invention, the steps (1), (2) and (3) were carried out using the following reactor. Step (1)

10 A microreactor (manufactured by IMM GmbH, Single Mixer Ver. 2, Inlay: Ag plating, fine liquid introducing channel width: 40 μ m) was used.

15 To each of two introduction channels for a sulfoxide-containing liquid and an activating agent-containing liquid for the sulfoxide compound, a SUS tube (inner diameter: 1.0 mm, length: 20 cm) was connected, and each channel was connected to a liquid supply source through the SUS tube.

Step (2)

20 A microreactor (the same as the microreactor for step (1)) was used. A reaction product liquid-discharging channel of the microreactor of step (1) was connected to a reaction product solution-introducing channel of the microreactor of the step (2) through a connecting SUS tube (inner diameter: 0.25 mm, length: 3.2 cm), and then an alcohol supply source was connected to an alcohol-introducing channel of a microreactor for step (2) through a SUS tube (inner diameter: 1.0 mm, length: 20 cm).

Step (3)

30 A microreactor (the same as the microreactor for step (1)) was used.

35 A reaction product solution-discharging channel of a microreactor of the step (2) was connected to a reaction product solution-introducing channel for the step (3) through a connecting SUS tube (inner diameter: 1.0 mm, length: 10 cm). Also, a basic compound-introducing channel of a microreactor for the step (3) was connected

to a basic compound supply source through a SUS tube
(inner diameter: 1.0 mm, length: 20 cm) and then a
reaction product solution-discharging SUS tube (inner
diameter: 1.0 mm, length: 20 cm) was connected to a
5 reaction product solution-discharging channel.

The microreactors for the steps (1), (2) and (3) and
the SUS tubes connected thereto were dipped in a constant
low-temperature bath set at a constant temperature of
-20°C.

10 By using a gas-tight syringe, a dimethyl
sulfoxide/methylene chloride solution having a
concentration of 2.0 mol/liter was fed into the
microreactor for step (1) at a flow rate of 4.0 ml/min
and a trifluoroacetic anhydride (TFAA)/methylene chloride
15 solution having a concentration of 3.0 mol/liter were
respectively fed into the microreactor for the step (1)
at a flow rate of 2.0 ml/min. Immediately after the
reaction mixture solution was retained for 0.02 seconds,
the reaction product solution was fed into the
20 microreactor for the step (2) and, at the same time, a
cyclohexanol/methylene chloride solution having a
concentration of 2.0 mol/liter was fed into the
microreactor for the step (2) at a flow rate of 2.0
ml/min. Immediately after the reaction mixture solution
25 was retained for 0.6 seconds, the reaction product
solution was fed into the microreactor for the step (3)
and, at the same time, triethylamine was fed at a flow
rate of 1.6 ml/min. After the above reaction operation
was carried out for 4 minutes, the reaction product
30 solution was discharged from the microreactor for the
step (3) and was collected in a sample bottle, containing
an internal standard substance, for one minute.

The contents of the collected compounds in the
reaction product solution was determined by a gas
35 chromatograph internal standard method. The results are
shown below.

Cyclohexanone

55%

Cyclohexyl trifluoroacetate	9%
Cyclohexyl methylthiomethyl ether	7%
Cyclohexanol	27%

Example 24

5 In the production of cyclohexanone from cyclohexanol
by the method of the present invention, the steps (1),
(2) and (3) were carried out using the following reactor.
Step (1)

10 A microreactor (manufactured by IMM GmbH, Single
Mixer Ver. 2, Inlay: Ag plating, fine liquid introducing
channel width: 40 μ m) was used.

15 To each of two introduction channels for a
sulfoxide-containing liquid and an activating agent-
containing liquid for the sulfoxide compound, a SUS tube
(inner diameter: 1.0 mm, length: 20 cm) was connected,
and each channel was connected to a liquid supply source
through the SUS tube.

Step (2)

20 A microreactor (the same as the microreactor for
step (1)) was used. A reaction product liquid
discharging channel of the microreactor of the step (1)
was connected to a reaction product solution introducing
channel of the microreactor of the step (2) through a
connecting SUS tube (inner diameter: 1.0 mm, length: 10
25 cm), and then an alcohol supply source was connected to
an alcohol introducing channel of a microreactor for the
step (2) through a SUS tube (inner diameter: 1.0 mm,
length: 20 cm).

Step (3)

30 A microreactor (the same as the microreactor for
step (1)) was used.

35 A reaction product solution-discharging channel of a
microreactor of step (2) was connected to a reaction
product solution-introducing channel for step (3) through
a connecting SUS tube (inner diameter: 1.0 mm, length: 10
cm). Also, a basic compound-introducing channel of a
microreactor for step (3) was connected to a basic

compound supply source through a SUS tube (inner diameter: 1.0 mm, length: 20 cm) and then a reaction product solution-discharging SUS tube (inner diameter: 1.0 mm, length: 20 cm) was connected to a reaction product solution-discharging channel.

The microreactors for the steps (1), (2) and (3) and the SUS tubes connected thereto were dipped in a constant low-temperature bath set at a constant temperature of -20°C .

By using a gas-tight syringe, a dimethyl sulfoxide/methylene chloride solution having a concentration of 2.0 mol/liter was fed into the microreactor for step (1) at a flow rate of 4.0 ml/min and a trifluoroacetic anhydride (TFAA)/methylene chloride solution having a concentration of 3.0 mol/liter were respectively fed into the microreactor for step (1) at a flow rate of 2.0 ml/min. Immediately after the reaction mixture solution was retained for 0.8 seconds, the reaction product solution was fed into the microreactor for step (2) and, at the same time, a cyclohexanol/methylene chloride solution having a concentration of 2.0 mol/liter was fed into the microreactor for the step (2) at a flow rate of 2.0 ml/min. Immediately after the reaction mixture solution was retained for 0.6 seconds, the reaction product solution was fed into the microreactor for the step (3) and, at the same time, triethylamine was fed at a flow rate of 1.6 ml/min. After the above reaction operation was carried out for 4 minutes, the reaction product solution was discharged from the microreactor for the step (3) and was collected in a sample bottle containing an internal standard substance for one minute.

The contents of the collected compounds in the reaction product solution were determined by a gas chromatograph internal standard method. The results are shown below.

Cyclohexanone

60%

Cyclohexyl trifluoroacetate	7%
Cyclohexyl methylthiomethyl ether	7%
Cyclohexanol	23%

Example 25

5 In the production of cyclohexanone from cyclohexanol by the method of the present invention, the steps (1), (2) and (3) were carried out using the following reactor. Step (1)

10 A microreactor (manufactured by IMM GmbH, Single Mixer Ver. 2, Inlay: Ag plating, fine liquid introducing channel width: 40 μ m) was used.

15 To each of two introduction channels for a sulfoxide-containing liquid and an activating agent-containing liquid for the sulfoxide compound, a SUS tube (inner diameter: 1.0 mm, length: 20 cm) was connected, and each channel was connected to a liquid supply source through the SUS tube.

Step (2)

20 A microreactor (the same as the microreactor for step (1)) was used. A reaction product liquid-discharging channel of the microreactor of the step (1) was connected to a reaction product solution-introducing channel of the microreactor of the step (2) through a connecting SUS tube (inner diameter: 1.0 mm, length: 10
25 cm), and then an alcohol supply source was connected to an alcohol-introducing channel of a microreactor for the step (2) through a SUS tube (inner diameter: 1.0 mm, length: 20 cm).

Step (3)

30 A microreactor (the same as the microreactor for step (1)) was used.

35 A reaction product solution-discharging channel of a microreactor of the step (2) was connected to a reaction product solution introducing channel for the step (3) through a connecting SUS tube (inner diameter: 1.0 mm, length: 10 cm). Also, a basic compound-introducing channel of a microreactor for the step (3) was connected

to a basic compound supply source through a SUS tube
(inner diameter: 1.0 mm, length: 20 cm) and then a
reaction product solution-discharging SUS tube (inner
diameter: 1.0 mm, length: 20 cm) was connected to a
5 reaction product solution-discharging channel.

The microreactors for the steps (1), (2) and (3) and
the SUS tubes connected thereto were dipped in a constant
low-temperature bath set at a constant temperature of
-30°C.

10 By using a gas-tight syringe, a dimethyl
sulfoxide/methylene chloride solution having a
concentration of 2.0 mol/liter was fed into the
microreactor for step (1) at a flow rate of 4.0 ml/min
and a trifluoroacetic anhydride (TFAA)/methylene chloride
15 solution having a concentration of 3.0 mol/liter was fed
into the microreactor for step (1) at a flow rate of 2.0
ml/min. Immediately after the reaction mixture solution
was retained for 0.8 seconds, the reaction product
solution was fed into the microreactor for step (2) and,
20 at the same time, a cyclohexanol/methylene chloride
solution having a concentration of 2.0 mol/liter was fed
into the microreactor for step (2) at a flow rate of 2.0
ml/min. Immediately after the reaction mixture solution
was retained for 0.6 seconds, the reaction product
25 solution was fed into the microreactor for step (3) and,
at the same time, triethylamine was fed at a flow rate of
1.6 ml/min. After the above reaction operation was
carried out for 4 minutes, the reaction product solution
was discharged from the microreactor for step (3) and was
30 collected in a sample bottle, containing an internal
standard substance, for one minute.

The contents of the collected compounds in the
reaction product solution were determined by a gas
chromatograph internal standard method. The results are
35 shown below.

Cyclohexanone	58%
Cyclohexyl trifluoroacetate	11%

Cyclohexyl methylthiomethyl ether	9%
Cyclohexanol	21%

Example 26

5 In the production of cyclohexanone from cyclohexanol
by the method of the present invention, the steps (1),
(2) and (3) were carried out using the following reactor.
Step (1)

10 A microreactor (manufactured by IMM GmbH, Single
Mixer Ver. 2, Inlay: Ag plating, fine liquid introducing
channel width: 40 μ m) was used.

To each of two introduction channels for a
sulfoxide-containing liquid and an activating agent-
containing liquid for the sulfoxide compound, a SUS tube
(inner diameter: 1.0 mm, length: 20 cm) was connected,
15 and each channel was connected to a liquid supply source
through the SUS tube.

Step (2)

A microreactor (the same as the microreactor for
step (1)) was used. A reaction product liquid-
20 discharging channel of the microreactor of step (1) was
connected to a reaction product solution-introducing
channel of the microreactor of step (2) using a
connecting SUS tube (inner diameter: 1.0 mm, length: 10
cm), and then an alcohol supply source was connected to
25 an alcohol-introducing channel of a microreactor for step
(2) through a SUS tube (inner diameter: 1.0 mm, length:
20 cm).

Step (3)

30 A microreactor (the same as the microreactor for
step (1)) was used.

A reaction product solution-discharging channel of a
microreactor of the step (2) was connected to a reaction
product solution-introducing channel of the microreactor
for the step (3) through a connecting SUS tube (inner
35 diameter: 0.25 mm, length: 3.2 cm). Also, a basic
compound-introducing channel of a microreactor for the
step (3) was connected to a basic compound supply source

through a SUS tube (inner diameter: 1.0 mm, length: 20 cm) and then a reaction product solution-discharging SUS tube (inner diameter: 1.0 mm, length: 20 cm) was connected to a reaction product solution-discharging channel.

The microreactors for the steps (1), (2) and (3) and the SUS tubes connected thereto were dipped in a constant low-temperature bath set at a constant temperature of -20°C .

By using a gas-tight syringe, a dimethyl sulfoxide/methylene chloride solution having a concentration of 2.0 mol/liter was fed into the microreactor for step (1) at a flow rate of 4.0 ml/min and a trifluoroacetic anhydride (TFAA)/methylene chloride solution having a concentration of 3.0 mol/liter was fed into the microreactor for step (1) at a flow rate of 2.0 ml/min. Immediately after the reaction mixture solution was retained for 0.8 seconds, the reaction product solution was fed into the microreactor for step (2) and, at the same time, a cyclohexanol/methylene chloride solution having a concentration of 2.0 mol/liter was fed into the microreactor for step (2) at a flow rate of 2.0 ml/min. Immediately after the reaction mixture solution was retained for 0.01 seconds, the reaction product solution was fed into the microreactor for the step (3) and, at the same time, triethylamine was fed at a flow rate of 1.6 ml/min. After the above reaction operation was carried out for 4 minutes, the reaction product solution was discharged from the microreactor for the step (3) and was collected in a sample bottle, containing an internal standard substance, for one minute.

The contents of the collected compounds in the reaction product solution were determined by a gas chromatograph internal standard method. The results are shown below.

Cyclohexanone	52%
Cyclohexyl trifluoroacetate	10%

Cyclohexyl methylthiomethyl ether	6%
Cyclohexanol	29%

Example 27

5 In the production of cyclohexanone from cyclohexanol
by the method of the present invention, the steps (1),
(2) and (3) were carried out using the following reactor.
Step (1)

10 A microreactor (manufactured by IMM GmbH, Single
Mixer Ver. 2, Inlay: Ag plating, fine liquid introducing
channel width: 40 μ m) was used.

To each of two introduction channels for a
sulfoxide-containing liquid and an activating agent-
containing liquid for the sulfoxide compound, a SUS tube
(inner diameter: 1.0 mm, length: 20 cm) was connected,
15 and each channel was connected to a liquid supply source
through the SUS tube.

Step (2)

A microreactor (the same as microreactor for the
step (1)) was used. A reaction product liquid-
20 discharging channel of the microreactor of step (1) was
connected to a reaction product solution-introducing
channel of the microreactor of step (2) through a
connecting SUS tube (inner diameter: 1.0 mm, length: 10
cm), and then an alcohol supply source was connected to
25 an alcohol-introducing channel of a microreactor for the
step (2) through a SUS tube (inner diameter: 1.0 mm,
length: 20 cm).

Step (3)

30 A microreactor (the same as the microreactor for
step (1)) was used.

A reaction product solution-discharging channel of a
microreactor of step (2) was connected to a reaction
product solution-introducing channel for step (3) using a
connecting SUS tube (inner diameter: 1.0 mm, length: 30
35 cm). Also, a basic compound-introducing channel of a
microreactor for step (3) was connected to a basic
compound supply source through a SUS tube (inner

diameter: 1.0 mm, length: 20 cm) and then a reaction product solution-discharging SUS tube (inner diameter: 1.0 mm, length: 20 cm) was connected to a reaction product solution-discharging channel.

5 The microreactors for the steps (1), (2) and (3) and the SUS tubes connected thereto were dipped in a constant low-temperature bath set at a constant temperature of -20°C.

10 By using a gas-tight syringe, a dimethyl sulfoxide/methylene chloride solution having a concentration of 2.0 mol/liter was fed into the microreactor for the step (1) at a flow rate of 4.0 ml/min and a trifluoroacetic anhydride (TFAA)/methylene chloride solution having a concentration of 3.0 mol/liter
15 was fed into the microreactor for step (1) at a flow rate of 2.0 ml/min. Immediately after the reaction mixture solution was retained for 0.8 seconds, the reaction product solution was fed into the microreactor for step (2) and, at the same time, a cyclohexanol/methylene
20 chloride solution having a concentration of 2.0 mol/liter was fed into the microreactor for step (2) at a flow rate of 2.0 ml/min. Immediately after the reaction mixture solution was retained for 1.8 seconds, the reaction product solution was fed into the microreactor for step
25 (3) and, at the same time, triethylamine was fed at a flow rate of 1.6 ml/min. After the above reaction operation was carried out for 4 minutes, the reaction product solution was discharged from the microreactor for step (3) and was collected in a sample bottle, containing
30 an internal standard substance, for one minute.

 The contents of the collected compounds in the reaction product solution were determined by a gas chromatograph internal standard method. The results are shown below.

35	Cyclohexanone	64%
	Cyclohexyl trifluoroacetate	6%
	Cyclohexyl methylthiomethyl ether	7%

Cyclohexanol

23%

Example 28

In the production of cyclohexanone from cyclohexanol by the method of the present invention, the steps (1),
5 (2) and (3) were carried out using the following reactor.
Step (1)

A microreactor (manufactured by IMM CO., Single Mixer Ver. 2, Inlay: Ag plating, fine liquid introducing channel width: 40 μ m) was used.

10 To each of two introduction channels for a sulfoxide-containing liquid and an activating agent-containing liquid for the sulfoxide compound, a SUS tube (inner diameter: 1.0 mm, length: 20 cm) was connected, and each channel was connected to a liquid supply source
15 through the SUS tube.

Step (2)

A microreactor (the same as the microreactor for step (1)) was used. A reaction product liquid-discharging channel of the microreactor of the step (1)
20 was connected to a reaction product solution introducing channel of the microreactor of the step (2) through a connecting SUS tube (inner diameter: 1.0 mm, length: 10 cm), and then an alcohol supply source was connected to an alcohol-introducing channel of a microreactor for step
25 (2) through a SUS tube (inner diameter: 1.0 mm, length: 20 cm).

Step (3)

A microreactor (the same as the microreactor for step (1)) was used.

30 A reaction product solution-discharging channel of a microreactor of step (2) was connected to a reaction product solution-introducing channel of the microreactor for step (3) through a connecting SUS tube (inner diameter: 1.0 mm, length: 10 cm). Also, a basic
35 compound-introducing channel of a microreactor for the step (3) was connected to a basic compound supply source through a SUS tube (inner diameter: 1.0 mm, length: 20

cm) and then a reaction product solution-discharging SUS tube (inner diameter: 1.0 mm, length: 20 cm) was connected to a reaction product solution-discharging channel.

5 The microreactors for the steps (1), (2) and (3) and the SUS tubes connected thereto were dipped in a constant low-temperature bath set at a constant temperature of -20°C.

10 By using a gas-tight syringe, a dimethyl sulfoxide/methylene chloride solution having a concentration of 2.2 mol/liter was fed into the microreactor for step (1) at a flow rate of 1.0 ml/min and a trifluoroacetic anhydride (TFAA)/methylene chloride solution having a concentration of 2.1 mol/liter was fed
15 into the microreactor for step (1) at a flow rate of 1.0 ml/min. Immediately after the reaction mixture solution was retained for 2.4 seconds, the reaction product solution was fed into the microreactor for step (2) and, at the same time, a cyclohexanol/methylene chloride
20 solution having a concentration of 1.0 mol/liter was fed into the microreactor for step (2) at a flow rate of 2.0 ml/min. Immediately after the reaction mixture solution was retained for 1.2 seconds, the reaction product solution was fed into the microreactor for the step (3)
25 and, at the same time, triethylamine was fed at a flow rate of 0.8 ml/min. After the above reaction operation was carried out for 4 minutes, the reaction product solution was discharged from the microreactor for step (3) and was collected in a sample bottle, containing an
30 internal standard substance, for one minute.

 The contents of the collected compounds in the reaction product solution were determined by a gas chromatograph internal standard method. The results are shown below.

35	Cyclohexanone	63%
	Cyclohexyl trifluoroacetate	6%
	Cyclohexyl methylthiomethyl ether	6%

Cyclohexanol

22%

Example 29

In the production of cyclohexanone from cyclohexanol by the method of the present invention, the steps (1),
5 (2) and (3) were carried out using the following reactor.
Step (1)

A microreactor (manufactured by IMM GmbH, Single Mixer Ver. 2, Inlay: Ag plating, fine liquid introducing channel width: 40 μm) was used.

10 To each of two introduction channels for a sulfoxide-containing liquid and an activating agent-containing liquid for the sulfoxide compound, a SUS tube (inner diameter: 1.0 mm, length: 20 cm) was connected, and each channel was connected to a liquid supply source
15 through the SUS tube.

Step (2)

A microreactor (the same as the microreactor for step (1)) was used. A reaction product liquid-discharging channel of the microreactor of step (1) was
20 connected to a reaction product solution-introducing channel of the microreactor of step (2) through a connecting SUS tube (inner diameter: 1.0 mm, length: 10 cm), and then an alcohol supply source was connected to an alcohol-introducing channel of a microreactor for step
25 (2) using a SUS tube (inner diameter: 1.0 mm, length: 20 cm).

Step (3)

A microreactor (the same as the microreactor for step (1)) was used.

30 A reaction product solution-discharging channel of a microreactor of step (2) was connected to a reaction product solution introducing channel for step (3) through a connecting SUS tube (inner diameter: 1.0 mm, length: 10 cm). Also, a basic compound-introducing channel of a
35 microreactor for step (3) was connected to a basic compound supply source through a SUS tube (inner diameter: 1.0 mm, length: 20 cm) and then a reaction

product solution-discharging SUS tube (inner diameter: 1.0 mm, length: 20 cm) was connected to a reaction product solution-discharging channel.

5 The microreactors for the steps (1), (2) and (3) and the SUS tubes connected thereto were dipped in a constant low-temperature bath set at a constant temperature of -20°C. To the end of the SUS tube for discharging a reaction product solution of the microreactor for step (3), a SUS tube (inner diameter: 1.0 mm, length: 100 cm)
10 was connected through a connecting tube (inner diameter: 1 mm, length: 50 cm) made of PTFE (polytetrafluoroethylene), and then only the connecting tube was dipped in a water bath at a temperature of 30°C.

15 By using a gas-tight syringe, a dimethyl sulfoxide/methylene chloride solution having a concentration of 2.2 mol/liter was fed into the microreactor for step (1) at a flow rate of 1.0 ml/min and a trifluoroacetic anhydride (TFAA)/methylene chloride solution having a concentration of 2.1 mol/liter was fed
20 into the microreactor for step (1) at a flow rate of 1.0 ml/min. Immediately after the reaction mixture solution was retained for 2.4 seconds, the reaction product solution was fed into the microreactor for step (2) and, at the same time, a cyclohexanol/methylene chloride
25 solution having a concentration of 1.0 mol/liter was fed into the microreactor for step (2) at a flow rate of 2.0 ml/min. Immediately after the reaction mixture solution was retained for 1.2 seconds, the reaction product solution was fed into the microreactor for step (3) and,
30 at the same time, triethylamine was fed at a flow rate of 0.8 ml/min. After the above reaction operation was carried out for 4 minutes, the reaction product solution was discharged from the microreactor for the step (3) and was collected in a sample bottle, containing an internal
35 standard substance, for one minute.

 The contents of the collected compounds in the reaction product solution were determined by a gas

chromatograph internal standard method. The results are shown below.

	Cyclohexanone	60%
	Cyclohexyl trifluoroacetate	8%
5	Cyclohexyl methylthiomethyl ether	5%
	Cyclohexanol	24%

Example 30

In the production of cyclohexanone from cyclohexanol by the method of the present invention, the steps (1),
10 (2) and (3) were carried out using the following reactor.
Step (1)

A microreactor (manufactured by GmbH, Single Mixer Ver. 2, Inlay: Ag plating, fine liquid introducing channel width: 40 μ m) was used.

15 To each of two introduction channels for a sulfoxide-containing liquid and an activating agent-containing liquid for the sulfoxide compound, a SUS tube (inner diameter: 1.0 mm, length: 20 cm) was connected, and each channel was connected to a liquid supply source
20 through the SUS tube.

Step (2)

A microreactor (the same as the microreactor for step (1)) was used. A reaction product liquid-discharging channel of the microreactor of step (1) was
25 connected to a reaction product solution-introducing channel of the microreactor of step (2) through a connecting SUS tube (inner diameter: 1.0 mm, length: 10 cm), and then an alcohol supply source was connected to an alcohol-introducing channel of a microreactor for step
30 (2) through a SUS tube (inner diameter: 1.0 mm, length: 20 cm).

Step (3)

A microreactor (the same as the microreactor for step (1)) was used.

35 A reaction product solution-discharging channel of a microreactor of step (2) was connected to a reaction product solution-introducing channel of the microreactor

for step (3) through a connecting SUS tube (inner diameter: 1.0 mm, length: 10 cm). Also, a basic compound-introducing channel of a microreactor for the step (3) was connected to a basic compound supply source through a SUS tube (inner diameter: 1.0 mm, length: 20 cm) and then a reaction product solution-discharging SUS tube (inner diameter: 1.0 mm, length: 20 cm) was connected to a reaction product solution-discharging channel.

The microreactors for the steps (1), (2) and (3) and the SUS tubes connected thereto were dipped in a constant low-temperature bath set at a constant temperature of -20°C . To the end of the SUS tube for discharging a reaction product solution of the microreactor for the step (3), a SUS tube (inner diameter: 1.0 mm, length: 100 cm) was connected through a connecting tube (inner diameter: 1 mm, length: 50 cm) made of PTFE (polytetrafluoroethylene), and then only the connecting tube was dipped in a water bath at a temperature of 30°C .

By using a gas-tight syringe, a dimethyl sulfoxide/methylene chloride solution having a concentration of 4.0 mol/liter and a trifluoroacetic anhydride (TFAA)/methylene chloride solution having a concentration of 3.0 mol/liter were respectively fed into the microreactor for step (1) at a flow rate of 1.0 ml/min, respectively. Immediately after the reaction mixture solution was retained for 2.4 seconds, the reaction product solution was fed into the microreactor for step (2) and, at the same time, a cyclohexanol/methylene chloride solution having a concentration of 1.0 mol/liter was fed into the microreactor for step (2) at a flow rate of 2.0 ml/min. Immediately after the reaction mixture solution was retained for 1.2 seconds, the reaction product solution was fed into the microreactor for step (3) and, at the same time, triethylamine was fed at a flow rate of 0.8 ml/min. After the above reaction operation was carried

out for 4 minutes, the reaction product solution was discharged from the microreactor for the step (3) and was collected in a sample bottle, containing an internal standard substance, for one minute.

5 The contents of the collected compounds in the reaction product solution were determined by a gas chromatograph internal standard method. The results are shown below.

	Cyclohexanone	62%
10	Cyclohexyl trifluoroacetate	6%
	Cyclohexyl methylthiomethyl ether	8%
	Cyclohexanol	21%

Comparative Example 1 (Batch Synthesis Comparative Example)

15 In an argon gas atmosphere, 1 ml of a dimethyl sulfoxide/methylene chloride solution having a concentration of 4 mol/liter was charged in a Schrenk tube having an inner volume of 30 ml and then cooled to a temperature of -23°C. While stirring this solution by
20 using a magnetic stirrer, 1 ml of a trifluoroacetic anhydride/methylene chloride solution having a concentration of 2.4 mol/liter was added dropwise to the solution at an addition rate of 0.1 ml/min, followed by mixing.

25 After the completion of the dropwise addition and mixing, the resultant mixture solution was stirred at the above temperature for 10 minutes. To this mixture solution, 2 ml of a decanol/methylene chloride solution having a concentration of 1.0 mol/liter was added
30 dropwise at an addition rate of 0.2 ml/min, followed by mixing.

 After the completion of the dropwise addition and mixing, the resultant mixture solution was stirred at the above-mentioned temperature for 10 minutes. To the
35 resultant mixture solution, 4 ml of a triethylamine/methylene chloride solution having a concentration of 1.5 mol/liter was added dropwise at an

addition rate of 0.4 ml/min, followed by mixing.

After the completion of the dropwise addition and mixing, the temperature of the resultant mixture solution was returned to room temperature and an internal standard agent was added thereto, and then the contents of the compounds in the mixture solution were measured by a gas chromatograph internal standard method. The measurement results are shown below.

	Decanal	8%
10	Decyl trifluoroacetate	66%
	Decyl methylthiomethyl ether	1%
	Decanol	27%

Comparative Example 2 (Batch Synthesis Comparative Example)

15 In an argon gas atmosphere, 1 ml of a dimethyl sulfoxide/methylene chloride solution having a concentration of 4 mol/liter was charged in a Schrenk tube having an inner volume of 30 ml and then cooled to a temperature of -23°C. While stirring this solution using a magnetic stirrer, 1 ml of a trifluoroacetic anhydride/methylene chloride solution having a concentration of 2.4 mol/liter was added dropwise to the solution at an addition rate of 0.1 ml/min, followed by mixing.

25 After the completion of the dropwise addition and mixing, the resultant mixture solution was stirred at the above temperature for 10 minutes. To this mixture solution, 2 ml of a 2-octanol/methylene chloride solution having a concentration of 1.0 mol/liter was added dropwise at an addition rate of 0.2 ml/min, followed by mixing.

35 After the completion of the dropwise addition and mixing, the resultant mixture solution was stirred at the above temperature for 10 minutes. To the resultant mixture solution, 4 ml of a triethylamine/methylene chloride solution having a concentration of 1.5 mol/liter was added dropwise at an addition rate of 0.4 ml/min,

followed by mixing.

After the completion of the dropwise addition and mixing, the temperature of the resultant mixture solution was returned to room temperature and an internal standard agent was added thereto, and then the contents of the compounds in the mixed solution were measured by a gas chromatograph internal standard method. The measurement results are shown below.

	2-octanone	10%
10	Octyl trifluoroacetate	38%
	Octyl methylthiomethyl ether	1%
	2-octanol	49%

Comparative Example 3 (Batch Synthesis Comparative Example)

15 In an argon gas atmosphere, 2 ml of a dimethyl sulfoxide/methylene chloride solution having a concentration of 4 mol/liter was charged in a Schrenk tube having an inner volume of 30 ml and then cooled to a temperature of -27°C. While stirring this solution using
20 a magnetic stirrer, 2 ml of a trifluoroacetic anhydride/methylene chloride solution having a concentration of 3.0 mol/liter was added dropwise to the solution at an addition rate of 0.2 ml/min, followed by mixing.

25 After the completion of the dropwise addition and mixing, the resultant mixture solution was stirred at the above temperature for 10 minutes. To this mixed solution, 4 ml of a cyclohexanol/methylene chloride solution having a concentration of 1.0 mol/liter was
30 added dropwise at an addition rate of 0.4 ml/min, followed by mixing.

After the completion of the dropwise addition and mixing, the resultant mixture solution was stirred at the above temperature for 10 minutes. To the resulting mixed
35 solution, 8 ml of a triethylamine/methylene chloride solution having a concentration of 1.4 mol/liter was added dropwise at an addition rate of 0.8 ml/min,

followed by mixing.

After the completion of the dropwise addition and mixing, the temperature of the resultant mixture solution was returned to room temperature and an internal standard agent was added thereto, and then the contents of the compounds in the mixed solution were measured by a gas chromatograph internal standard method. The measurement results are shown below.

	Cyclohexanone	45%
10	Cyclohexyl trifluoroacetate	11%
	Cyclohexyl methylthiomethyl ether	5%
	Cyclohexanol	36%

Comparative Example 4 (Batch Synthesis Comparative Example)

In an argon gas atmosphere, 1 ml. of a dimethyl sulfoxide/methylene chloride solution having a concentration of 4 mol/liter was charged in a Schrenk tube having an inner volume of 30 ml and then cooled to a temperature of -23°C. While stirring this solution using a magnetic stirrer, 1 ml of a trifluoroacetic anhydride/methylene chloride solution having a concentration of 2.4 mol/liter was added dropwise to the solution at an addition rate of 0.1 ml/min, followed by mixing.

After the completion of the dropwise addition and mixing, the resultant mixture solution was stirred at the above temperature for 10 minutes. To this mixed solution, 2 ml of a cyclohexanol/methylene chloride solution having a concentration of 1.0 mol/liter was added dropwise at an addition rate of 0.2 ml/min, followed by mixing.

After the completion of the dropwise addition and mixing, the resultant mixture solution was stirred at the above temperature for 10 minutes. To the resulting mixed solution, 4 ml of a triethylamine/methylene chloride solution having a concentration of 1.5 mol/liter was added dropwise at an addition rate of 0.4 ml/min,

followed by mixing.

After the completion of the dropwise addition and mixing, the temperature of the resultant mixture solution was returned to room temperature and an internal standard agent was added thereto, and then the contents of the compounds in the mixed solution were measured by a gas chromatograph internal standard method. The measurement results are shown below.

	Cyclohexanone	16%
10	Cyclohexyl trifluoroacetate	60%
	Cyclohexyl methylthiomethyl ether	2%
	Cyclohexanol	14%

Comparative Example 5 (Batch Synthesis Comparative Example)

15 In an argon gas atmosphere, 1 ml of a dimethyl sulfoxide/methylene chloride solution having a concentration of 4 mol/liter was charged in a Schrenk tube having an inner volume of 30 ml and then cooled to a temperature of -23°C. While stirring this solution using
20 a magnetic stirrer, 1 ml of a trifluoroacetic anhydride/methylene chloride solution having a concentration of 2.4 mol/liter was added dropwise to the solution at an addition rate of 0.1 ml/min, followed by mixing.

25 After the completion of the dropwise addition and mixing, the resultant mixture solution was stirred at the above temperature for 10 minutes. To this mixed solution, 2 ml of a benzyl alcohol/methylene chloride solution having a concentration of 1.0 mol/liter was
30 added dropwise at an addition rate of 0.2 ml/min, followed by mixing.

After the completion of the dropwise addition and mixing, the resultant mixture solution was stirred at the above temperature for 10 minutes. To the resulting mixed
35 solution, 4 ml of a triethylamine/methylene chloride solution having a concentration of 1.5 mol/liter was added dropwise at an addition rate of 0.4 ml/min,

followed by mixing.

After the completion of the dropwise addition and mixing, the temperature of the resultant mixture solution was returned to room temperature and an internal standard agent was added thereto, and then the contents of the compounds in the mixed solution were measured by a gas chromatograph internal standard method. The measurement results are shown below.

	Benzaldehyde	39%
10	Benzyl trifluoroacetate	40%
	Benzyl alcohol	20%

Examples 31 to 39 (Example of synthesis of decanal, 2-octanone or benzaldehyde from decanol, 2-octanol or benzyl alcohol by using Single Mixer manufactured by IMM GmbH under the conditions of a reaction temperature of -10 to 20°C and a reaction time of 0.01 seconds)

In each of Examples 31 to 39, SUS tubes were connected to three Single Mixers Ver. 2 (Inlay: made of Ag plating, fine liquid introducing channel width: 40 μm) manufactured by IMM GmbH (Germany) to constitute a reaction apparatus. A SUS tube (inner diameter = 1.0 mm, length = 20 cm) was connected to each of two reaction reagent inlets of the first unit and then a reaction solution outlet of the first unit was connected to one of two reaction reagent inlets of the second unit through a SUS tube (inner diameter = 0.1 mm, length = 3.2 cm). A SUS tube (inner diameter = 1.0 mm, length = 20 cm) was connected to the other reaction reagent inlet of the second unit and then the reaction solution outlet of the second unit was connected to one of two reaction reagent inlets of the third unit through a SUS tube (inner diameter = 1.0 mm, length = 10 cm). A SUS tube (inner diameter = 1.0 mm, length = 20 cm) was connected to the other reaction reagent inlet of the third unit and then a SUS tube (inner diameter = 1.0 mm, length = 20 cm) was connected to a reaction solution outlet of the third unit. The upper portion of the present apparatus was

dipped in a constant low-temperature water bath at a predetermined temperature described in Table 1.

Furthermore, a SUS tube (inner diameter = 1.0 mm, length = 100 cm) was connected to the outlet of the apparatus
5 through a PTFE connecting tube (inner diameter = 1.0 mm, length = 50 cm). Only this connecting tube was dipped in a water bath at 30°C.

By using a gas-tight syringe manufactured by Hamilton Co., a dimethyl sulfoxide/methylene chloride
10 solution having a concentration of 4.0 mol/L and a trifluoroacetic anhydride/methylene chloride solution having a concentration of 2.4 mol/L were respectively fed through two inlets of the first unit at a rate of 1.0 mL/min (step 1), and then the reaction product solution
15 of the first unit was rapidly fed into one of two inlets of the second unit from the reaction solution outlet of the first unit and a reactant/methylene chloride solution having a concentration of 1.0 mol/L was fed through the other inlet of the second unit at a rate of 2.0 mL/min
20 (step 2). The reaction product solution was rapidly fed into one of two inlets of the third unit through the reaction solution outlet of the second unit, and then a triethylamine/methylene chloride solution having a concentration of 1.4 mol/L was fed through the other
25 inlet of the third unit at a rate of 4.0 mL/min (step 3). After feeding the solution for 4 minutes, the reaction solution produced in the third unit was sampled into sample bottle containing an internal standard substance through the outlet of the third unit. The yield of the
30 product was determined by a GC internal standard method.

The Reactant (starting compound) fed into the second unit and the target reaction product obtained from the third unit are as follows.

Examples 31 to 33

35 Starting substance: Decanol

Target reaction product: Decanal

Examples 34 to 36

Starting substance: 2-octanol

Target reaction product: 2-octanone

Examples 37 to 39

Starting substance: Benzyl alcohol

5 Target reaction product: Benzaldehyde

The reaction results are shown in Table 1.

Table 1

Example No.	Starting Substance	Reaction temperature (°C)	Yield (%)			
			Product	TFA ester	MTM ether	Non-reacted starting substance
31	Decanol	-10	66* ₁	20* ₄	7* ₇	7
32	Decanol	0	66* ₁	21* ₄	6* ₇	6
33	Decanol	20	68* ₁	21*	6* ₇	4
34	2-octanol	-10	78* ₂	3* ₅	4* ₈	10
35	2-octanol	0	78* ₂	3* ₅	4* ₈	9
36	2-octanol	20	78* ₂	2* ₅	3* ₈	12
37	Benzyl alcohol	-10	79* ₃	15* ₆	Uncalculated	1
38	Benzyl alcohol	0	78* ₃	14* ₆	Uncalculated	0
39	Benzyl alcohol	20	75* ₃	16* ₆	Uncalculated	0

(Note) *₁: Decanal

*₂: 2-octanone

10 *₃: Benzaldehyde

*₄: Decyl trifluoroacetate

*₅: Octyl trifluoroacetate

*₆: Benzyl trifluoroacetate

*₇: Decyl methylthiomethyl ether

15 *₈: Octyl methylthiomethyl ether

Examples 40 to 41 (Example of synthesis of cyclohexanone from cyclohexanol by using Single Mixer manufactured by IMM GmbH under the conditions of a reaction temperature of 10°C and -10°C and a reaction time of 0.01 seconds)

20 In each of Examples 40 and 41, SUS tubes were

connected to three Single Mixers Ver. 2 (Inlay: made of Ag plating, fine liquid introducing channel width: 40 μ m) manufactured by IMM GmbH (Germany) to constitute a reaction apparatus. A SUS tube (inner diameter = 1.0 mm, length = 20 cm) was connected to each of two reaction reagent inlets of the first unit and then a reaction solution outlet of the first unit was connected to one of two reaction reagent inlets of the second unit through a SUS tube (inner diameter = 0.1 mm, length = 3.2 cm). A SUS tube (inner diameter = 1.0 mm, length = 20 cm) was connected to the other reaction reagent inlet of the second unit and then the reaction solution outlet of the second unit was connected to one of two reaction reagent inlets of the third unit through a SUS tube (inner diameter = 1.0 mm, length = 10 cm). A SUS tube (inner diameter = 1.0 mm, length = 20 cm) was connected to the other reaction reagent inlet of the third unit and then a SUS tube (inner diameter = 1.0 mm, length = 20 cm) was connected to a reaction solution outlet of the third unit. The upper portion of the present apparatus was dipped in a constant low temperature water bath at a predetermined temperature described in Table 2. Furthermore, a SUS tube (inner diameter = 1.0 mm, length = 100 cm) was connected to the outlet of the apparatus using a PTFE connecting tube (inner diameter = 1.0 mm, length = 50 cm). This connecting portion was dipped in a water bath at 30°C.

By using a gas-tight syringe manufactured by Hamilton Co., a dimethyl sulfoxide/methylene chloride solution having a concentration of 4.0 mol/L and a trifluoroacetic anhydride/methylene chloride solution having a concentration of 2.4 mol/L were respectively fed through two inlets of the first unit at a rate of 1.0 mL/min (step 1), and then the reaction product solution of the first unit was rapidly fed into one of two inlets of the second unit from the reaction solution outlet of the first unit and a cyclohexanol/methylene chloride

solution having a concentration of 1.0 mol/L was fed through the other inlet of the second unit at a rate of 2.0 mL/min (step 2). The reaction product solution was rapidly fed from the reaction solution outlet of the second unit into one of two inlets of the third unit, and then a triethylamine/methylene chloride solution having a concentration of 1.5 mol/L was fed through the other inlet of the third unit at a rate of 4.0 mL/min (step 3). After feeding the solution for 4 minutes, the reaction solution produced in the third unit was sampled into sample bottle containing an internal standard substance from the outlet of the third unit. The yield of the product was determined by a GC internal standard method. The reaction results are shown in Table 2.

Table 2

Example No.	Starting Substance	Reaction temperature (°C)	Yield (%)			
			Product * ₉	TFA ester * ₁₀	MTM ether * ₁₁	Non-reacted Starting Substance
40	Cyclohexanol	-10	78	5	5	11
41	Cyclohexanol	10	80	4	4	9

(Note) *₉: Cyclohexanone
*₁₀: Cyclohexyl trifluoroacetate
*₁₁: Cyclohexyl methylthiomethyl ether

Example 42 (Example of synthesis of cyclohexanone from cyclohexanol by using Single Mixer manufactured by IMM GmbH under the conditions of a reaction temperature of 0°C and a reaction time of 0.1 seconds)

SUS tubes were connected to three Single Mixers Ver. 2 (Inlay: made of Ag plating, fine liquid introducing channel width: 40 µm) manufactured by IMM GmbH (Germany) to constitute a reaction apparatus. A SUS tube (inner diameter = 1.0 mm, length = 20 cm) was connected to each of two reaction reagent inlets of the first unit and then a reaction solution outlet of the first unit was

connected to one of two reaction reagent inlets of the second unit through a SUS tube (inner diameter = 0.25 mm, length = 6.8 cm). A SUS tube (inner diameter = 1.0 mm, length = 20 cm) was connected to the other reaction reagent inlet of the second unit and then the reaction solution outlet of the second unit was connected to one of two reaction reagent inlets of the third unit through a SUS tube (inner diameter = 1.0 mm, length = 10 cm). A SUS tube (inner diameter = 1.0 mm, length = 20 cm) was connected to the other reaction reagent inlet of the third unit and then a SUS tube (inner diameter = 1.0 mm, length = 20 cm) was connected to a reaction solution outlet of the third unit. The upper portion of the present apparatus was dipped in a constant low temperature water bath at 0°C. Furthermore, a SUS tube (inner diameter = 1.0 mm, length = 100 cm) was connected to the outlet of the apparatus through a PTFE connecting tube (inner diameter = 1.0 mm, length = 50 cm). This connecting portion was dipped in a water bath at 30°C.

By using a gas-tight syringe manufactured by Hamilton Co., a dimethyl sulfoxide/methylene chloride solution having a concentration of 4.0 mol/L and a trifluoroacetic anhydride/methylene chloride solution having a concentration of 2.4 mol/L were respectively fed from two inlets of the first unit at a rate of 1.0 mL/min (step 1), and then the reaction product solution of the first unit was rapidly fed from the reaction solution outlet of the first unit into one of two inlets of the second unit and a cyclohexanol/methylene chloride solution having a concentration of 1.0 mol/L was fed into the second unit through the other inlet of the second unit at a rate of 2.0 mL/min (step 2). The reaction product solution was rapidly fed from the reaction solution outlet of the second unit into one of two inlets of the third unit, and then a triethylamine/methylene chloride solution having a concentration of 1.5 mol/L was fed into the third unit through the other inlet of the

third unit at a rate of 4.0 mL/min (step 3). After feeding the solution for 4 minutes, the reaction solution produced in the third unit was sampled into sample bottle containing an internal standard substance through the outlet of the third unit. The yield of the product was determined by a GC internal standard method. The reaction results are shown in Table 3.

Table 3

Example No.	Starting Substance	Reaction temperature (°C)	Yield (%)			
			Product * ₉	TFA ester * ₁₀	MTM ether * ₁₁	Non-reacted Starting Substance
42	Cyclohexanol	0	74	4	3	8

(Note) *₉: Cyclohexanone
 *₁₀: Cyclohexyl trifluoroacetate
 *₁₁: Cyclohexyl methylthiomethyl ether

Examples 43 to 46 (Example of synthesis of cyclohexanone from cyclohexanol by using Single Mixer manufactured by IMM GmbH under the conditions of a reaction temperature of -20 to 10°C and a reaction time of 0.5 seconds)

In each of Examples 43 to 46, SUS tubes were connected to three Single Mixers Ver. 2 (Inlay: made of Ag plating, fine liquid introducing channel width: 40 μm) manufactured by IMM GmbH (Germany) to constitute a reaction apparatus. A SUS tube (inner diameter = 1.0 mm, length = 20 cm) was connected to each of two reaction reagent inlets of the first unit and then a reaction solution outlet of the first unit was connected to one of two reaction reagent inlets of the second unit through a SUS tube (inner diameter = 0.5 mm, length = 8.5 cm). A SUS tube (inner diameter = 1.0 mm, length = 20 cm) was connected to the other reaction reagent inlet of the second unit and then the reaction solution outlet of the second unit was connected to one of two reaction reagent inlets of the third unit through a SUS tube (inner diameter = 1.0 mm, length = 10 cm). A SUS tube (inner

diameter = 1.0 mm, length = 20 cm) was connected to the other reaction reagent inlet of the third unit and then a SUS tube (inner diameter = 1.0 mm, length = 20 cm) was connected to a reaction solution outlet of the third unit. The upper portion of the present apparatus was dipped in a constant low temperature water bath at a predetermined temperature described in Table 4.

Furthermore, a SUS tube (inner diameter = 1.0 mm, length = 100 cm) was connected to the outlet of the apparatus through a PTFE connecting tube (inner diameter = 1.0 mm, length = 50 cm). This connecting portion was dipped in a water bath at 30°C.

By using a gas-tight syringe manufactured by Hamilton Co., a dimethyl sulfoxide/methylene chloride solution having a concentration of 4.0 mol/L and a trifluoroacetic anhydride/methylene chloride solution having a concentration of 2.4 mol/L were respectively fed through two inlets of the first unit at a rate of 1.0 mL/min (step 1), and then the reaction product solution of the first unit was rapidly fed into one of two inlets of the second unit through the reaction solution outlet of the first unit and a cyclohexanol/methylene chloride solution having a concentration of 1.0 mol/L was fed from the other inlet of the second unit at a rate of 2.0 mL/min (step 2). The reaction product solution was rapidly fed into one of two inlets of the third unit through the reaction solution outlet of the second unit, and then a triethylamine/methylene chloride solution having a concentration of 1.5 mol/L was fed through the other inlet of the third unit at a rate of 4.0 mL/min (step 3). After feeding the solution for 4 minutes, the reaction solution produced in the third unit was sampled into sample bottle containing an internal standard substance through the outlet of the third unit. The yield of the product was determined by a GC internal standard method. The reaction results are shown in Table 4.

Table 4

Example No.	Starting Substance	Reaction temperature (°C)	Yield (%)			
			Product * ₉	TFA ester * ₁₀	MTM ether * ₁₁	Non-reacted Starting Substance
43	Cyclohexanol	-20	77	5	5	11
44		-10	76	5	5	10
45		0	77	3	3	8
46		10	73	3	4	17

(Note) *₉: Cyclohexanone
 *₁₀: Cyclohexyl trifluoroacetate
 *₁₁: Cyclohexyl methylthiomethyl ether

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Example 47 (Example of synthesis of cyclohexane from cyclohexanol by using Single Mixer manufactured by IMM GmbH under the conditions of a reaction temperature of 0°C and a reaction time of 1.2 seconds)

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SUS tubes were connected to three Single Mixers Ver. 2 (Inlay: made of Ag plating, fine liquid introducing channel width: 40 µm) manufactured by IMM GmbH (Germany) to constitute a reaction apparatus. A SUS tube (inner diameter = 1.0 mm, length = 20 cm) was connected to each of two reaction reagent inlets of the first unit and then a reaction solution outlet of the first unit was

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connected to one of two reaction reagent inlets of the second unit through a SUS tube (inner diameter = 1 mm, length = 5 cm). A SUS tube (inner diameter = 1.0 mm, length = 20 cm) was connected to the other reaction reagent inlet of the second unit and then the reaction solution outlet of the second unit was connected to one of two reaction reagent inlets of the third unit through a SUS tube (inner diameter = 1.0 mm, length = 10 cm). A SUS tube (inner diameter = 1.0 mm, length = 20 cm) was connected to the other reaction reagent inlet of the third unit and then a SUS tube (inner diameter = 1.0 mm,

20

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length = 20 cm) was connected to a reaction solution outlet of the third unit. The upper portion of the present apparatus was dipped in a low and constant-temperature water bath at 0°C. Furthermore, a SUS tube
5 (inner diameter = 1.0 mm, length = 100 cm) was connected to the outlet of the apparatus through a PTFE connecting tube (inner diameter = 1.0 mm, length = 50 cm). This connecting portion was dipped in a water bath at 30°C.

By using a gas-tight syringe manufactured by
10 Hamilton Co., a dimethyl sulfoxide/methylene chloride solution having a concentration of 4.0 mol/L and a trifluoroacetic anhydride/methylene chloride solution having a concentration of 2.4 mol/L were respectively fed through two inlets of the first unit at a rate of 1.0
15 mL/min (step 1), and then the reaction product solution of the first unit was rapidly fed from the reaction solution outlet of the first unit into one of two inlets of the second unit and a cyclohexanol/methylene chloride solution having a concentration of 1.0 mol/L was fed
20 through the other inlet of the second unit at a rate of 2.0 mL/min (step 2). The reaction product solution was rapidly fed from the reaction solution outlet of the second unit into one of two inlets of the third unit, and then a triethylamine/methylene chloride solution having a
25 concentration of 1.5 mol/L was fed through the other inlet of the third unit at a rate of 4.0 mL/min (step 3). After feeding the solution for 4 minutes, the reaction solution produced in the third unit was sampled from the outlet of the third unit into sample bottle containing an
30 internal standard substance. The yield of the product was determined by a GC internal standard method. The reaction results are shown in Table 5.

Table 5

Example No.	Starting Substance	Reaction temperature (°C)	Yield (%)			
			Product * ₉	TFA ester * ₁₀	MTM ether * ₁₁	Non-reacted Starting Substance
47	Cyclohexanol	0	69	2	2	17

(Note) *₉: Cyclohexanone
 *₁₀: Cyclohexyl trifluoroacetate
 *₁₁: Cyclohexyl methylthiomethyl ether

5

Example 48 (Example of synthesis of cyclohexanone from cyclohexanol by using Single Mixer manufactured by IMM GmbH under the conditions of a reaction temperature of 0°C and a reaction time of 1.6 seconds)

10 SUS tubes were connected to three Single Mixers Ver. 2 (Inlay: made of Ag plating, fine liquid introducing channel width: 40 µm) manufactured by IMM GmbH (Germany) to constitute a reaction apparatus. A SUS tube (inner diameter = 1.0 mm, length = 20 cm) was connected to each
 15 of two reaction reagent inlets of the first unit and then a reaction solution outlet of the first unit was connected to one of two reaction reagent inlets of the second unit through a SUS tube (inner diameter = 1 mm, length = 7 cm). A SUS tube (inner diameter = 1.0 mm, length = 20 cm) was connected to the other reaction
 20 reagent inlet of the second unit and then the reaction solution outlet of the second unit was connected to one of two reaction reagent inlets of the third unit through a SUS tube (inner diameter = 1.0 mm, length = 10 cm). A SUS tube (inner diameter = 1.0 mm, length = 20 cm) was connected to the other reaction reagent inlet of the
 25 third unit and then a SUS tube (inner diameter = 1.0 mm, length = 20 cm) was connected to a reaction solution outlet of the third unit. The upper portion of the present apparatus was dipped in a constant low-
 30 temperature water bath at 0°C. Furthermore, a SUS tube

(inner diameter = 1.0 mm, length = 100 cm) was connected to the outlet of the apparatus through a PTFE connecting tube (inner diameter = 1.0 mm, length = 50 cm). This connecting portion was dipped in a water bath at 30°C.

5 Using a gas-tight syringe manufactured by Hamilton Co., a dimethyl sulfoxide/methylene chloride solution having a concentration of 4.0 mol/L and a trifluoroacetic anhydride/methylene chloride solution having a concentration of 2.4 mol/L were respectively fed through
10 two inlets of the first unit at a rate of 1.0 mL/min (step 1), and then the reaction product solution of the first unit was rapidly fed from the reaction solution outlet of the first unit into one of two inlets of the second unit and a cyclohexanol/methylene chloride
15 solution having a concentration of 1.0 mol/L was fed through the other inlet of the second unit at a rate of 2.0 mL/min (step 2). The reaction product solution was rapidly fed from the reaction solution outlet of the second unit into one of two inlets of the third unit, and
20 then a triethylamine/methylene chloride solution having a concentration of 1.5 mol/L was fed through the other inlet of the third unit at a rate of 4.0 mL/min (step 3). After feeding the solution for 4 minutes, the reaction solution produced in the third unit was sampled from the
25 outlet of the third unit into sample bottle containing an internal standard substance. The yield of the product was determined by a GC internal standard method. The reaction results are shown in Table 6.

Table 6

Example No.	Starting Substance	Reaction temperature (°C)	Yield (%)			
			Product * ₉	TFA ester * ₁₀	MTM ether * ₁₁	Non-reacted Starting Substance
48	Cyclohexanol	0	64	4	2	18

30 (Note) *₉: Cyclohexanone
 *₁₀: Cyclohexyl trifluoroacetate
 *₁₁: Cyclohexyl methylthiomethyl ether

Example 49 (Example of synthesis of cyclohexanone from cyclohexanol by using Single Mixer manufactured by IMM GmbH under the conditions of a reaction temperature of -10°C and a reaction time of 2.4 seconds)

SUS tubes were connected to three Single Mixers Ver. 2 (Inlay: made of Ag plating, fine liquid introducing channel width: 40 μ m) manufactured by IMM GmbH (Germany) to constitute a reaction apparatus. A SUS tube (inner diameter = 1.0 mm, length = 20 cm) was connected to each of two reaction reagent inlets of the first unit and then a reaction solution outlet of the first unit was connected to one of two reaction reagent inlets of the second unit through a SUS tube (inner diameter = 1 mm, length = 10 cm). A SUS tube (inner diameter = 1.0 mm, length = 20 cm) was connected to the other reaction reagent inlet of the second unit and then the reaction solution outlet of the second unit was connected to one of two reaction reagent inlets of the third unit through a SUS tube (inner diameter = 1.0 mm, length = 10 cm). A SUS tube (inner diameter = 1.0 mm, length = 20 cm) was connected to the other reaction reagent inlet of the third unit and then a SUS tube (inner diameter = 1.0 mm, length = 20 cm) was connected to a reaction solution outlet of the third unit. The upper portion of the present apparatus was dipped in a constant low temperature water bath at a predetermined temperature of -10°C. Furthermore, a SUS tube (inner diameter = 1.0 mm, length = 100 cm) was connected to the outlet of the apparatus through a PTFE connecting tube (inner diameter = 1.0 mm, length = 50 cm). This connecting portion was dipped in a water bath at 30°C.

By using a gas-tight syringe manufactured by Hamilton Co., a dimethyl sulfoxide/methylene chloride solution having a concentration of 4.0 mol/L and a trifluoroacetic anhydride/methylene chloride solution

having a concentration of 2.4 mol/L were respectively fed through two inlets of the first unit at a rate of 1.0 mL/min (step 1), and then the reaction product solution of the first unit was rapidly fed from the reaction solution outlet of the first unit into one of two inlets of the second unit and a cyclohexanol/methylene chloride solution having a concentration of 1.0 mol/L was fed through the other inlet of the second unit at a rate of 2.0 mL/min (step 2). The reaction product solution was rapidly fed from the reaction solution outlet of the second unit into one of two inlets of the third unit, and then a triethylamine/methylene chloride solution having a concentration of 1.5 mol/L was fed through the other inlet of the third unit at a rate of 4.0 mL/min (step 3). After feeding the solution for 4 minutes, the reaction solution produced in the third unit was sampled from the outlet of the third unit into sample bottle containing an internal standard substance. The yield of the product was determined by a GC internal standard method. The reaction results are shown in Table 7.

Table 7

Example No.	Starting Substance	Reaction temperature (°C)	Yield (%)			
			Product * ₉	TFA ester * ₁₀	MTM ether * ₁₁	Non-reacted Starting Substance
49	Cyclohexanol	-10	80	4	5	10

(Note) *₉: Cyclohexanone
*₁₀: Cyclohexyl trifluoroacetate
*₁₁: Cyclohexyl methylthiomethyl ether

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Examples 50 to 52 (Example of synthesis of cyclohexanone from cyclohexanol by using Single Mixer manufactured by IMM GmbH under the conditions of a reaction temperature of -20°C, 0°C or 20°C and a reaction time R1 of 0.01 seconds and R2 of 0.02 seconds)

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In each of Examples 50 to 52, SUS tubes were connected to three Single Mixers Ver. 2 (Inlay: made of

Ag plating, fine liquid introducing channel width: 40 μm)
manufactured by IMM GmbH (Germany) to constitute a
reaction apparatus. A SUS tube (inner diameter = 1.0 mm,
length = 20 cm) was connected to each of two reaction
5 reagent inlets of the first unit and then a reaction
solution outlet of the first unit was connected to one of
two reaction reagent inlets of the second unit through a
SUS tube (inner diameter = 0.1 mm, length = 3.2 cm). A
SUS tube (inner diameter = 1.0 mm, length = 20 cm) was
10 connected to the other reaction reagent inlet of the
second unit and then the reaction solution outlet of the
second unit was connected to one of two reaction reagent
inlets of the third unit through a SUS tube (inner
diameter = 0.25 mm, length = 3.2 cm). A SUS tube (inner
15 diameter = 1.0 mm, length = 20 cm) was connected to the
other reaction reagent inlet of the third unit and then a
SUS tube (inner diameter = 1.0 mm, length = 20 cm) was
connected to a reaction solution outlet of the third
unit. The upper portion of the present apparatus was
20 dipped in a constant low-temperature water bath at a
predetermined temperature described in Table 8.
Furthermore, a SUS tube (inner diameter = 1.0 mm, length
= 100 cm) was connected to the outlet of the apparatus
using a PTFE connecting tube (inner diameter = 1.0 mm,
25 length = 50 cm). This connecting portion was dipped in a
water bath at 30°C.

By using a gas-tight syringe manufactured by
Hamilton Co., a dimethyl sulfoxide/methylene chloride
solution having a concentration of 4.0 mol/L and a
30 trifluoroacetic anhydride/methylene chloride solution
having a concentration of 2.4 mol/L were respectively fed
into the first unit through two inlets of the first unit
at a rate of 1.0 mL/min (step 1), and then the reaction
product solution of the first unit was rapidly fed from
35 the reaction solution outlet of the first unit into one
of two inlets of the second unit and a
cyclohexanol/methylene chloride solution having a

concentration of 1.0 mol/L was fed through the other inlet of the second unit at a rate of 2.0 mL/min (step 2). The reaction product solution of the first unit was rapidly fed from the reaction solution outlet of the second unit into one of two inlets of the third unit, and then a triethylamine/methylene chloride solution having a concentration of 1.4 mol/L was fed into the third unit through the other inlet of the third unit at a rate of 4.0 mL/min (step 3). After feeding the solution for 4 minutes, the reaction solution produced in the third unit was sampled from the outlet of the third unit into sample bottle containing an internal standard substance. The yield of the product was determined by a GC internal standard method. The reaction results are shown in Table 8.

Table 8

Example No.	Starting Substance	Reaction temperature (°C)	Yield %)			
			Product * ₉	TFA ester * ₁₀	MTM ether * ₁₁	Non-reacted Starting Substance
50	Cyclohexanol	-20	75	4	3	8
51		0	76	3	3	8
52		20	81	3	2	7

(Note) *₉: Cyclohexanone
 *₁₀: Cyclohexyltrifluoro acetate
 *₁₁: Cyclohexyl methylthiomethyl ether

Example 53 and 54 (Example of synthesis of cyclohexanone from cyclohexanol by using Single Mixer manufactured by IMM GmbH under the conditions of a reaction temperature of -20°C or 0°C and a reaction time of 0.01 seconds)

In each of Examples 53 and 54, SUS tubes were connected to three Single Mixers Ver. 2 (Inlay: made of Ag plating, fine liquid introducing channel width: 40 μm) manufactured by IMM GmbH (Germany) to constitute a reaction apparatus. A SUS tube (inner diameter = 1.0 mm,

length = 20 cm) was connected to each of two reaction reagent inlets of the first unit and then a reaction solution outlet of the first unit was connected to one of two reaction reagent inlets of the second unit through a SUS tube (inner diameter = 0.1 mm, length = 3.2 cm). A SUS tube (inner diameter = 1.0 mm, length = 20 cm) was connected to the other reaction reagent inlet of the second unit and then the reaction solution outlet of the second unit was connected to one of two reaction reagent inlets of the third unit through a SUS tube (inner diameter = 1.0 mm, length = 10 cm). A SUS tube (inner diameter = 1.0 mm, length = 20 cm) was connected to the other reaction reagent inlet of the third unit and then a SUS tube (inner diameter = 1.0 mm, length = 20 cm) was connected to a reaction solution outlet of the third unit. The upper portion of the present apparatus was dipped in a low and constant-temperature water bath at a predetermined temperature described in Table 9. Furthermore, a SUS tube (inner diameter = 1.0 mm, length = 100 cm) was connected to the outlet of the apparatus using a PTFE connecting tube (inner diameter = 1.0 mm, length = 50 cm). This connecting portion was dipped in a water bath at 30°C.

By using a gas-tight syringe manufactured by Hamilton Co., a dimethyl sulfoxide/methylene chloride solution having a concentration of 2.0 mol/L and a trifluoroacetic anhydride/methylene chloride solution having a concentration of 2.0 mol/L were respectively fed into the first unit through two inlets of the first unit at a rate of 1.0 mL/min (step 1), and then the reaction product solution of the first unit was rapidly fed from the reaction solution outlet of the first unit into one of two inlets of the second unit and a cyclohexanol/methylene chloride solution having a concentration of 1.0 mol/L was fed into the other inlet of the second unit at a rate of 2.0 mL/min (step 2). The reaction product solution was rapidly fed from the

reaction solution outlet of the second unit into one of two inlets of the third unit and, then, a triethylamine/methylene chloride solution having a concentration of 1.5 mol/L was fed into the other inlet of the third unit at a rate of 4.0 mL/min (step 3). After feeding the solution for 4 minutes, the reaction solution produced in the third unit was sampled from the outlet of the third unit into sample bottle containing an internal standard substance. The yield of the product was determined by a GC internal standard method. The reaction results are shown in Table 9.

Table 9

Example No.	Starting Substance	Reaction temperature (°C)	Yield (%)			
			Product * ₉	TFA ester * ₁₀	MTM ether * ₁₁	Non-reacted Starting Substance
53	Cyclohexanol	-20	69	8	4	12
54		0	66	8	4	13

(Note) *₉: Cyclohexanone

*₁₀: Cyclohexyl trifluoroacetate

*₁₁: Cyclohexyl methylthiomethyl ether

Examples 55 and 56 (Example of synthesis of cyclohexanone from cyclohexanol by using Single Mixer manufactured by IMM GmbH under the conditions of a reaction temperature of -20°C or 0°C and a reaction time of 0.01 seconds)

In each of Examples 55 and 56, SUS tubes were connected to three Single Mixers Ver. 2 (Inlay: made of Ag plating, fine liquid introducing channel width: 40 μm) manufactured by IMM Co. (Germany) to constitute a reaction apparatus. A SUS tube (inner diameter = 1.0 mm, length = 20 cm) was connected to each of two reaction reagent inlets of the first unit and then a reaction solution outlet of the first unit was connected to one of two reaction reagent inlets of the second unit through a SUS tube (inner diameter = 0.1 mm, length = 3.2 cm). A SUS tube (inner diameter = 1.0 mm, length = 20 cm) was

connected to the other reaction reagent inlet of the second unit and then the reaction solution outlet of the second unit was connected to one of two reaction reagent inlets of the third unit through a SUS tube (inner
5 diameter = 1.0 mm, length = 10 cm). A SUS tube (inner diameter = 1.0 mm, length = 20 cm) was connected to the other reaction reagent inlet of the third unit and then a SUS tube (inner diameter = 1.0 mm, length = 20 cm) was connected to a reaction solution outlet of the third
10 unit. The upper portion of the present apparatus was dipped in a low-temperature water bath at a predetermined temperature shown in Table 10. Furthermore, a SUS tube (inner diameter = 1.0 mm, length = 100 cm) was connected to the outlet of the apparatus using a PTFE connecting
15 tube (inner diameter = 1.0 mm, length = 50 cm). This connecting portion was dipped in a water bath at 30°C.

By using a gas-tight syringe manufactured by Hamilton Co., a dimethyl sulfoxide/methylene chloride solution having a concentration of 4.0 mol/L and a
20 trifluoroacetic anhydride/methylene chloride solution having a concentration of 2.0 mol/L were respectively fed into the first unit through two inlets of the first unit at a rate of 1.0 mL/min (step 1), and then the reaction product solution of the first unit was rapidly fed from
25 the reaction solution outlet of the first unit into one of two inlets of the second unit and a cyclohexanol/methylene chloride solution having a concentration of 1.0 mol/L was fed into the second unit through the other inlet of the second unit at a rate of
30 2.0 mL/min (step 2). The reaction product solution was rapidly fed from the reaction solution outlet of the second unit into one of two inlets of the third unit, and then a triethylamine/methylene chloride solution having a concentration of 1.5 mol/L was fed into the third unit
35 through the other inlet of the third unit at a rate of 4.0 mL/min (step 3). After feeding the solution for 4 minutes, the reaction solution produced in the third unit

was sampled from the outlet of the third unit into sample bottle containing an internal standard substance. The yield of the product was determined by a GC internal standard method. The reaction results are shown in Table 10.

Table 10

Example No.	Starting Substance	Reaction temperature (°C)	Yield (%)			
			Product * ₉	TFA ester * ₁₀	MTM ether * ₁₁	Non-reacted Starting Substance
55	Cyclohexanol	-20	70	3	4	13
56		0	73	3	4	15

(Note) *₉: Cyclohexanone
*₁₀: Cyclohexyl trifluoroacetate
*₁₁: Cyclohexyl methylthiomethyl ether

INDUSTRIAL APPLICABILITY

The method of the present invention enables the production of a aldehyde or ketone compound from a corresponding primary alcohol or secondary alcohol at a comparatively high temperature, compared to the low temperature of -30°C or lower in a conventional method, within a short time and with a high yield. Therefore it is practically useful.